Chapter 6
HMS ESSENTIAL FISH HABITAT (EFH) PROVISIONS

6.1 Introduction

For highly mobile, pelagic species such as tuna, swordfish, and sharks, defining EFH offers unique challenges. Collectively, these species are widely dispersed in oceanic, neritic (waters over the continental shelf), coastal and estuarine waters and move frequently over great horizontal distances, commonly migrating vertically within the water column. [In the following accounts, these movements will only be referred to as migrations for those species for which there is evidence of seasonality or regularity.]

The NMFS regulatory interpretation of the 1996 Magnuson-Stevens Act (i.e., the EFH regulations) requires that NMFS and the regional fishery management councils use the best available scientific information to determine EFH for all managed species. As described in Chapter 5 an initial review of available literature and information was undertaken to assess habitat use and ecological roles of the species in the HMS fishery management unit. Published and unpublished scientific reports, fishery independent and fishery dependent data, and expert and anecdotal information detailing the habitats used by the managed species were evaluated and synthesized for inclusion in this FMP (Section 6.3). Habitats that satisfy the criteria in the Magnuson-Stevens Act and the EFH regulations have been identified and described as EFH; some additional habitats that have been identified as necessary for a sustainable fishery but that lie outside the U.S. Exclusive Economic Zone (EEZ), and therefore cannot be identified as EFH under the Magnuson-Stevens Act (e.g., the Gulf of Guinea off the African coast), have been highlighted as particularly important habitats for HMS, as suggested in the EFH regulations.

Identifying EFH for tuna, swordfish and many pelagic shark species is challenging because, although some HMS may frequent the neritic waters of the continental shelf as well as inshore areas, they are primarily blue-water (i.e., open-ocean) species. Their distributions are usually not correlated with the areas or features one commonly thinks of as fish habitat and for which one can describe parameters such as bottom sediment type or vegetative density (e.g., seagrass beds or estuarine subtidal rocky bottoms). These fishes most often associate with physiographic structures of the water column (features including oceanic fronts, river plumes, current boundaries, shelf edges, sea mounts, and temperature discontinuities, and the interactions of these); it is these features that must be characterized as habitat for the pelagic life stages of these species. Distribution of juveniles, adults, and especially early life stages (larvae for tuna and swordfish; neonates for sharks) may be constrained by tolerance of temperature, salinity or oxygen levels. These physicochemical properties may be used to define the boundaries of essential habitat in a broad sense. However, even when these parameters and tolerances are well understood and can be used to define the limits of a habitat, the distribution of these characteristics is not fixed in space or time, but varies over seasons and years. Although the EFH regulations allow for inferring habitat between species with similar ecological niches, the basic lack of knowledge of the proximate factors that attract HMS to particular habitats precludes inference of EFH between these species at this time. By including a review of the ecological roles of HMS as predator and prey, the FMP establishes a framework for using a broader ecosystem approach to evaluating habitat use and EFH requirements that will be pursued in future amendments.

The EFH regulations also require the identification of actions that may adversely affect EFH, and conservation measures to mitigate those potential threats. Many of the threats originate in inshore or estuarine areas but have the potential to impact offshore habitats because of current patterns in the nearshore and on the continental shelf that move materials out to deeper regions. The wide distribution of the HMS and their EFH requires that a broad approach to habitat protection be taken. Many of the sharks use estuarine and coastal waters, particularly for mating, pupping and neonate stages. Loss of these crucial habitats has been highlighted as a concern of shark researchers, who for many years have warned of concomitant declines in productivity.

Habitat protection is equally important for the pelagic life stages of sharks, swordfish and tuna. In spite of the apparent distance of their prime habitats from shore, they are susceptible to adverse effects from inshore activities because their distributions are correlated with river plumes, current boundaries, canyons and convergence zones which either serve to transport or concentrate materials directly into offshore habitats. In addition, various life stages of most of these species frequent coastal habitats. Threats to EFH from both fishing and non-fishing activities are treated in detail under Section 6.6.

6.2 EFH Identification Processes

6.2.1 Process Used for Identification of EFH for Tuna and Swordfish

There is evidence that certain areas, such as spawning grounds, serve important habitat functions for tuna and swordfish, either throughout the year or seasonally. Although actual spawning has not been observed for many of these species, the presence of eggs and larvae is frequently used as a proxy for spawning areas. Therefore, the location of spawning grounds has only been defined in a very broad sense. It is not known which parameters, beyond some temperature boundaries, define these as appropriate spawning areas. Additionally, eggs and larvae of these species are some of the rarest collected, and the picture of spawning and distribution of eggs and larvae is far from complete. Larvae and juveniles have a rapid growth rate, and few specimens, especially of early juveniles, are ever collected. When larvae have been collected, their identification to species has proven to be very difficult and it must be assumed that many earlier identifications have been incorrect (W.J. Richards, per. comm.). In some cases even the identification of adults is problematic and therefore caution is required when interpreting data. It is clear that much more research is needed on spawning grounds, species identifications, and habitat requirements before areas of importance to tuna and swordfish can be more clearly delineated.

Under the Magnuson-Stevens Act EFH includes areas necessary for feeding. Tuna and swordfish may exhibit different feeding characteristics in different parts of their ranges. While researchers have identified relative proportions of prey in tuna and swordfish diets, it appears that they are opportunistic feeders able to exploit a large diversity of fishes, cephalopods and crustaceans. This precludes using the distributions of major prey species as indicators of HMS EFH. Additional research into prey dynamics is necessary to gain a better understanding of the importance of prey species to tuna and swordfish. It is suggested that tuna and swordfish associate with water column structures because they offer prime feeding opportunities; these structural habitats tend to coincide with areas of upwelling, convergence zones, and other hydrographic features. In addition, much of the information on the distribution of tuna and swordfish suggests that the utilization of these feeding areas has a temporal or seasonal component that should be more fully explored and delineated in future research.

There is little additional information to help define EFH for these species. Some species appear to be primarily distributed above the thermocline or between certain isotherms; these temperature limits may define the outer boundaries of EFH for those species. As indicated above, some species aggregate at frontal boundaries in the ocean, with floating objects (such as *Sargassum*), or at bottom features such as the continental shelf break, submarine canyons, and even shipwrecks. Occasionally, the aggregations form where a front or boundary lies above one of these bottom features. These aggregations are most likely associated with prime feeding grounds and, as such, these areas are identified as EFH.

As discussed in Chapter 5 *Sargassum* has been identified as important habitat for many fish species. HMS (e.g., swordfish) have also been found associated with *Sargassum*, and are known to frequent various types of drift materials. However, the importance of *Sargassum* as habitat for HMS remains unclear, as the few scientific investigations conducted to-date have collected limited numbers of individuals. Further complicating the determination of *Sargassum*'s importance to HMS is that floating mats tend to aggregate along convergence zones and fronts, areas where HMS are known to gather even in the absence of *Sargassum*. Clearly, more investigations are needed to gain a better understanding of the role of *Sargassum* concerning HMS. At this time, however, when *Sargassum* is present in areas that have been designated EFH for HMS, it is also considered EFH, as it has been recognized to be an important biological component of those areas. Further discussion concerning *Sargassum* can be found in Section 6.6.

Based on the available data or scientific knowledge, EFH for tuna and swordfish has been identified for each species. Life history stages have been combined into ecological groupings indicative of habitat use:

- "**Spawning, eggs and larvae**" largely depend on spawning locations and water motion to control their distributions. Spawning locations are identified based on published accounts that identify concentrations of spawning activity or extrapolate probable locations upcurrent of egg and larval distributions.

- "**Juveniles and subadults**" are swimming stages that show increased mobility patterns and develop transient lifestyles. Some fish in this size class are taken by targeted fishing and as bycatch.

- "**Adults**" are fish that are sexually mature; the size criterion is "those fish greater than or equal to the size at first maturation of females."

The current EFH descriptions and delineations for tuna and swordfish conform to the standards proposed by the NMFS regulations. Since the current status of the scientific knowledge of these species is such that habitat preferences are largely undefined or are difficult to determine, EFH is based on presence/absence and relative abundance data, as available. To the extent that environmental information is available, it has been included in the EFH descriptions. The most common factors included are temperature and salinity ranges, depths (isobaths), and association with particular water masses or currents. The textual accounts for each species serve as the legal description of EFH, and where environmental characterizations are known they have been included. Maps are provided as supplemental material to facilitate visualization of the EFH locations. Based on analyses of the available data, shaded polygons marking the outer boundaries of EFH for each life stage have been drawn on the maps. Locations within the boundaries of EFH for a species' life stage that do not meet the added environmental factors provided (e.g., salinity or temperature) are not considered EFH.

The life history accounts (Section 6.3) detail what is known about each species' life history, distribution and ecological roles as they relate to habitat use. Current status of the fishery is included since it may have implications in the current or historic range of the species. "U.S. Fishery Status" is based on the most recent NMFS report to Congress, required under the Magnuson-Stevens Act, "Status of Fisheries of the United States," October 1998.

In general, the designations of EFH for tuna and swordfish as they currently stand are a combination of life history information, expert opinion regarding the importance of certain areas, and presence/absence and relative abundance information from fishery independent and dependent sources. It should be noted that much of the work on the basic ecology of these fishes is not recent; most is from the 1980s or before. Without more basic research on life history, habitat use, behavior and distribution of all life stages of tuna and swordfish, defining EFH for these species will continue to be difficult.

6.2.2 Process Used for Identification of EFH for Atlantic Sharks

Defining the habitat of sharks found in the temperate zone is difficult because most species are highly mobile or migratory, utilizing diverse habitats in apparently non-specific or poorly understood ways. Most migratory sharks traverse a variety of habitats in their movements. Generally, the migrations of sharks are poorly understood, and can be defined only in very broad terms. In addition, the different life stages[1] of a given shark species are often found in different habitats. In most cases the neonates (newborn) and juveniles occupy different habitats than the adults. For example, neonate blacktip sharks are found in very shallow waters, juvenile blacktip sharks inhabit a variety of coastal habitats, and adults are found in both coastal and oceanic waters. There is little published information correlating life stages and migratory movements, and there are few descriptions correlating shark habitat use to physical habitat characteristics. Parameters that could describe shark habitat are temperature, salinity, depth, dissolved oxygen, light levels, substrate, and food availability, although there are probably other important factors or requirements that remain unknown.

[1] The life history of sharks is generally divided into four stages: embryo, neonate, juvenile, and adult (Castro, 1993b). The neonates are recently born young bearing fresh umbilical scars (in the case of placental sharks) or those at or near the birth size (in the case of aplacental sharks). Juveniles are all the post-neonatal individuals prior to sexual maturation. Adults are the sexually mature individuals of the population.

Temperature is a primary factor affecting the migration and distribution of sharks. Thus, the movements of sharks in coastal waters of the temperate zone are usually correlated with seasonal changes in water temperature, as these animals attempt to remain within their temperature tolerance limits. Most of the coastal species of sharks undertake north-south migrations that coincide with the change of seasons.

Warm-water adapted species of sharks are found off Florida and in Caribbean waters during the winter. They travel northward in the spring, spending the summer in the warm waters off Georgia, the Carolinas, and Virginia. When the water temperature drops in mid-October these species migrate southward again towards warmer waters. Cold-water adapted species spend their summer in the high latitudes off eastern Canada and migrate southward in the winter to areas off Virginia and North Carolina. Some species migrate seasonally from shallower waters inhabited in the summertime to deeper, more temperature-stable waters during the winter. In addition, some sharks also perform diurnal (day-night) movements, either from deep water during the daytime to shallow waters at night, or from deep water to surface water. Some pelagic species may have very large home ranges, their movements perhaps covering entire ocean basins and conducted over long time scales.

Since temperature is likely the most important factor in defining the habitat of sharks, it may be appropriate, in some cases, to define the habitat of a shark species by the location of a given isotherm at a given time of the year. However, even though this may be applicable in the case of pelagic or migratory species, it is unlikely to be sufficient for describing the habitat of coastal species. Obviously, there are other factors that control the distribution of coastal species, although less is known about them.

Salinity is another factor that may influence the distribution of sharks. However, salinity data is generally an unreliable descriptor for defining the habitat of coastal shark species. First, many coastal species inhabit estuaries where the salinity fluctuates widely, or where fresher water may overlay deeper, more saline waters (such as in highly stratified estuaries). Thus, salinity often depends on when or where it is measured, and such data may not accurately reflect the conditions where the sharks were encountered. Second, many of the coastal species have a wide salinity tolerance. For example, the Mote Marine Laboratory Center for Shark Research (CSR) data show that blacktip sharks have been captured in salinities ranging from 15.8 to 37.0 parts per thousand (ppt), and bull sharks in salinities ranging from 3.0 to 28.5 ppt sharks (bull sharks are known to enter fresh water and live in salt water of 36 ppt). Other factors must contribute significantly to the distribution of sharks; likely parameters include light levels, pressure, substrate, and dissolved oxygen, although there may be others.

Within the constraints of current knowledge, any generalizations on the habitat of a given coastal shark species can be made only in very broad terms. Given the lack of precise data to define the habitat characteristics of sharks in a specific and consistent manner, a more practical approach may be to define the habitat by geographic location instead of by the physical parameters within that location. For example: neonate blacktip sharks have been reported in Bulls Bay, SC, by Castro (1993b) and in Charlotte Harbor, FL, by Hueter (CSR data). In South Carolina the sharks are found over shallow muddy bottoms while in Florida blacktip sharks are found over shallow, clear waters with seagrass beds. In both cases blacktip sharks have been found over a wide range of temperatures and salinities. However, the habitats have not been sufficiently studied to allow us to find what the common parameters are, if any. Thus, based on these two studies, one can only say that blacktips have nurseries in Bulls Bay and in Charlotte Harbor; it is impossible to accurately predict why. This approach has been embraced in our approach of using spatial data coupled with expert knowledge in our analysis of EFH for Atlantic sharks.

EFH has been identified for each shark species for which there were available data or scientific knowledge. Many of the dominant species of the fisheries display complex habitat use that varies with ontogenetic development. Although there is considerable controversy over the proper terminology and delineation of the various life stages of sharks, we have avoided that academic debate and grouped life stages into three classifications based on general shifts in habitat use. For the analysis we have used the large coastal sharks (LCS) and some of their habitat use characteristics as our model. As temperatures warm in the spring or summer, species such as blacktip and sandbar move north along the coast. Pups (neonates) are born in specific areas (e.g., estuaries or coastal habitats) and they typically remain in the same general area until temperatures cool in the late fall or early winter. At that time they typically move offshore and/or southward, although the extent of these movements is not well defined. The following year their seasonal movements change, more closely mimicking the migrations of the adults, until they actually join the adult migrations in subsequent years. For purposes of this FMP we tried to capture these three variations in habitat use[2]. Our smallest size class, "neonates and early juveniles," includes both the life stage traditionally defined as neonates (see footnote p. 6) and the animals that remain in the same or adjacent habitats throughout that first warm season. Assuming that birth of the pups could occur early in the season, and a late arrival of winter, the longest period for this initial habitat use might be nine to ten months. Size at one-year is a reasonable approximation of the size at which this habitat shift occurs. We have identified this upper boundary (length-at-age-1) for the smallest size of the various species (1) from published information; (2) from calculating size-at-age using the von Bertalanffy growth functions; or (3) by estimating the growth rate based on ecologically and biologically similar species for which (1) or (2) was available. The largest size class, "Adults," is intended to portray age at maturity and is based on the size at first maturity for females of the species. Frequently in the literature the size-at-maturity criteria have not been specified and in those cases we have used the lengths as cited. The middle size range, "juveniles and subadults," is a cumulative group into which all life stages between age one and maturity have been lumped. This size class may frequently show the largest distribution, based on their continued return to inshore habitats and their developing conformity to adult migration patterns. Additionally, we have identified EFH Habitat Areas of Particular Concern (HAPC) for the sandbar shark where, based on the criteria proposed in the EFH regulations, the data support the designation.

The current EFH descriptions and delineations for sharks conform to the standards proposed in the NMFS regulations. Since the current status of the scientific knowledge of

[2] The suggestion was considered, to modify the names of the three size classes by using the following: 1) Pupping, neonates and young-of-the-year; 2) Juveniles; and 3) Adults. These terms are comparable to those used in this document. While we realize that the terminology we have used is not necessarily consistent with all scientific opinions, the authors feel that the size classes used in this document are adequately defined for the reader to understand our intention and we believe that the classes realistically represent habitat use by life stage.

these species is such that habitat preferences are largely undefined or are difficult to determine, EFH is based on presence/absence and relative abundance data, as available. To the extent that environmental information is available, it has been included in the EFH descriptions. The most common factors included are temperature and salinity ranges, depths (isobaths), seasons, and association with particular water masses or currents. The textual accounts for each species serve as the legal description of EFH, and where environmental characterizations are known they have been included. Maps are provided as supplemental material to facilitate visualization of the EFH locations. Based on analyses of the available data, shaded polygons marking the outer boundaries of EFH for each life stage have been drawn on the maps. Locations within the boundaries of EFH for a species' life stage that do not meet the added environmental factors (e.g., salinity or temperature) are not considered EFH.

The life history accounts (Section 6.3) detail what is known about each species' life history, distribution and ecological roles as they relate to habitat use. Current status of the fishery is included since the current or historic range of the species may affect habitat use. "U.S. Fishery Status" is based on the most recent NMFS report to Congress, required under the Magnuson-Stevens Act, "Status of Fisheries of the United States," October 1998. For some species inadequate information is currently available to evaluate species-specific stock status; for these species stock status is derived from an analysis of the management group, e.g., large coastal sharks. This is the best information on stock status available at this time, both for management of the species group and for analyzing species habitat use.

In general, the designations of EFH for sharks as they currently stand are a combination of life history information, expert opinion regarding the importance of certain areas, and a combination of presence/absence and relative abundance information from fishery independent and dependent sources, analyzed using Geographic Information System (GIS) technology. It should be noted that much of the work on the basic ecology of these fishes is on-going. Without more basic research on life history, habitat use, behavior and distribution of different life stages, it will continue to be difficult to define EFH for these species.

6.2.3 Methodology for Identification of EFH for HMS

Determining EFH for HMS presents special concerns that can be addressed in a number of ways. Preferentially, relevant habitat use information could be combined with habitat quality and quantity data and species abundance information to produce models of likely areas of habitat preference that could then be prioritized and protected. Alternatively, temporally variable environmental conditions that constrain habitat use (e.g., temperature extremes, physical features such as density fronts, etc) could be mapped and serve as limiting boundaries to exclude unavailable habitats. An ideal model might incorporate both methods; however, development of such analyses is time consuming and costly for species for which this data exist, and impossible for those species for which it is incomplete.

The inference of EFH based on species locational information, such as presence/absence and catch data, requires the identification of important caveats. Misinterpretation or misuse of such data may result in the protection of marginal habitats or the exclusion of very important habitats. In circumstances where questions of delineating EFH arose, the precautionary approach was employed; however, to minimize the potential misidentification of EFH, multiple data sets were evaluated. Criteria were developed to minimize concerns regarding the incorporation and analysis of both fisheries dependent and fisheries independent data sets. Chief among these concerns was the spatial and temporal extent of the studies that have generated the data. The accuracy of the data, especially in the identification of certain species and in the reporting of length of individual fish, was also considered. Comparisons between disparate data sets (and the lack of full corroboration between them) were performed cautiously and provide additional room for improvement in subsequent FMP amendments. Finally, given the congressional deadlines and the large number of species and geographic area involved, the analyses and EFH designations as they now stand are primarily limited by time and effort.

In order to proceed cautiously with our analyses, while still meeting the mandated deadline for this FMP, certain priorities of data gathering and presentation were identified. We constrained our efforts to large-scale data sets, with spatial coverage of a minimum of several states and preferentially of the entire north Atlantic and Caribbean, including areas beyond the U.S. EEZ. In addition, we favored data sets with a large temporal extent. In certain instances this was not possible, and a single year of observations was included. Many fisheries dependent data sets are limited temporally; however, we have been able to incorporate data from two long-term studies that reach into the 1940s and 1960s, respectively.

To visually represent species presence/absence, data were analyzed using a GIS. Once an overall range was established using multiple data sets, a refinement of our understanding of each species consisted of analyses within data sets of the location and characteristics of individual fish (e.g., length, sex, date of capture), where possible, and a comparison of areas of aggregation, either through a thorough analysis of absolute catch (i.e., numbers of fish caught) or a preponderance of locational data. In many cases these exercises were restricted by specific types of data (e.g., locational data for tagging-based data sets, or catch data for fishery reporting data sets); two observer program data sets allowed for both types of analyses.

Noticeable areas of aggregations, as bounded by some easily identifiable geographic feature or description (e.g., bathymetry, distance from shore, etc), were delineated as EFH for each relevant species life stages. Where expert opinion was available and data points were scarce, areas were defined as EFH based on our best interpretation of our life history accounts; this became especially important for spawning areas, nursery grounds and eggs and larvae, since no data sets that met our criteria were available. EFH boundaries were digitized and processed into maps to supplement the text descriptions and tabular information provided in this FMP. Only those habitats that occur within the boundaries as they are interpreted through the text, maps and tables in conjunction are considered EFH. For example, within any given EFH boundary on a map, “essential” habitats occur; the boundary does not encompass all habitats within it as essential, unless the text and tables indicate so. In any case where the text description of EFH and the map supporting that description conflict, the legal definition of EFH lies with the text and tables.

Data Sets Utilized to Assist the Delineation of Essential Fish Habitat

The primary source of data that satisfied our initial criteria for spatial and temporal coverage was the NMFS Southeast Fisheries Science Center (SEFSC) in Miami, FL. The commercial pelagic longline fleet is monitored from this laboratory. This is done in two ways. Under one monitoring program fishing boat captains must keep a log of the fish they have caught by location, recording species, number of fish kept or discarded, and information on effort and gear. This information is reported to the NMFS SEFSC where the Pelagic Longline Logbook data base is maintained. We have queried this database for 1992 to 1997 for the species managed under this FMP. Considering the large amount of records maintained in this database, we have binned, or aggregated, the catch information into 0.5 degree cells based on latitude and longitude. This data set does not provide information on individual fish caught. However, it may be assumed that discards represent fish under the size limit for that species; therefore, limited size information is available for targeted species in the aggregate.

Under another monitoring program the same commercial pelagic longline fleet is monitored by the SEFSC through the Southeast Observer Program. This program places trained observers on board commercial fishing boats. The observers record information on location, number of fish caught per set, effort and gear as well as the characteristics of individual fish such as sex, length, weight, condition, etc. Realistically, this program represents a more accurate sub-sample of the Pelagic Longline Logbook. While it may be assumed that trained observers can and do make positive identifications and accurate measurements, these data cannot be solely relied upon. The primary limitations of this database are a lack of consistent coverage throughout the EEZ and a small number of records, especially for incidentally encountered species. However, other data can be corroborated using Southeast Observer Program data, and coverage is sufficient to rely on this database for some species (e.g., swordfish, some tuna).

The SEFSC in Miami also houses a long-term data set administered by The Billfish Foundation. Since the 1940s large pelagic species have been caught, tagged, released alive and recaptured to investigate the extent of their horizontal, sometimes transoceanic, movements. This data set provides presence/absence locational data of a tagged position as well as some length and sex information (often estimated). The primary utility of this data for EFH purposes is its long-term nature, which allows for an analysis of the historical range of a species. This “Release and Recapture” database also has the largest spatial extent of any of our databases. Primary limitations include a lack of confidence in species identifications for more difficult species of sharks, for example, and the lack of accurate (measured) size data. These data are primarily the result of years of tagging by recreational fishermen, although commercial fishermen and academicians have contributed as well.

The databases discussed above provide suitable coverage of pelagic waters of the United States, which is often acceptable for many HMS; however, additional information is needed to provide an adequate picture of shark locations and aggregations. Many sharks utilize inshore habitats not sampled or fished regularly by the pelagic longline fleet. In addition, many NMFS nearshore fisheries surveys use gear that is easily avoided by sharks. However, the NMFS Cooperative Shark Tagging Program, a directed shark tagging program managed out of the Northeast Fisheries Science Center (NEFSC) laboratory in Narragansett, RI, has provided 30 years of locational data for many species of sharks, and enough records on size and sex of frequently encountered species to allow a fairly rigorous investigation into size class distributions. Tags are distributed to scientists and commercial and recreational fisherman who release the sharks after recording locational information, and, when possible, gender and estimated or measured lengths and weights. This has been the primary data set utilized for shark EFH designations, providing over 15,000 records alone for the sandbar shark. It is, however, not without limitations. Since many sharks are difficult to identify to species, much of the information is considered suspect unless corroborated by identification by a scientist or by an observer from the Southeast Observer Program. For some species this reduces the number of useful data points dramatically, especially when corroboration by other data or expert opinion is not available. Another limitation is the lack of measured lengths, which may restrict the use of specific size classes to represent habitat usage patterns by life stage.

The last data set to be incorporated for consistent use into our analyses is the Shark Observer Program administered by the Ichthyology Department of the Florida Museum of Natural History. This program is similar to the Southeast Observer Program in that trained observers record catch per set, as well as information on individual sharks such as length, weight and sex. These data have been used to corroborate the non-scientist identifications of the NMFS Cooperative Shark Tagging Program, as well as to provide additional coverage where the spatial coverage of that data set is insufficient. The identifications and measurements are considered accurate; however, the number of data points for some species is very low, and coverage extends only from North Carolina to the west coast of Florida.

Other data sets that have been used sparingly or will be added in future FMP revisions include state inshore surveys such as those run by the South Carolina Department of Natural Resources and the Virginia Institute of Marine Science Longline Survey, and additional fisheries reporting data such as the Large Pelagic Survey, which is a recreational and commercial rod and reel dockside survey database from the northeast United States. Data sets that provide a high degree of confidence in species identification and lengths are of high priority. Also, spatial information gaps have been identified in the west Gulf of Mexico, especially offshore Louisiana, and in Puerto Rico and the U.S. Virgin Islands. In addition, data on water column characteristics (e.g., temperature, salinity, etc) and habitats will improve future analyses of spatial and temporal coverage for the HMS EFH designations.

6.3 Life History Accounts and Essential Fish Habitat Descriptions[3]

6.3.1 Tuna

6.3.1.1 Atlantic Albacore (*Thunnus alalunga*)

[3] Supplemental materials referenced in these accounts may be found in Section 6.4 (Tables): Summary Tables of Life History and Habitat Associations.; and Section 6.5 (Figures): Essential Fish Habitat (EFH) Maps (by species and life stage).

Distribution: Albacore is a circumglobal species. In the west Atlantic albacore range from 40 to 45° N to 40° S. It is an epipelagic, oceanic species generally found in surface waters with temperatures between 15.6° and 19.4° C, although larger individuals have a wider depth and temperature range (13.5° to 25.2° C). Albacore may dive into cold water (9.5° C) for short periods, and can be found at depths up to 600 m in the Atlantic. However, they do not tolerate oxygen levels lower than two milliliter/liter (ml/l). Albacore undergo extensive horizontal movements. Aggregations are composed of similarly sized individuals with groups comprised of the largest individuals making the longest journeys. Aggregations of albacore may include other tuna species such as skipjack, yellowfin and bluefin tuna. North Atlantic and south Atlantic stocks are considered separate, with no evidence of mixing between the two (ICCAT, 1997; Collette and Nauen, 1983).

Predator–prey relationships: A wide variety of fishes and invertebrates have been found in the few stomachs of albacore tuna that have been examined. As with other tuna, albacore probably exhibit opportunistic feeding behavior, with little reliance on specific prey items. (Dragovich, 1969; Matthews *et al.*, 1977).

Life history: Albacore spawn in the spring and summer in the western tropical Atlantic (ICCAT, 1997). Larvae are also taken in the Mediterranean Sea and historically in the Black Sea (Vodyanitsky and Kazanova, 1954).

Fisheries: For assessment purposes, three stocks of albacore are assumed: north and south Atlantic stocks (separated at 5° N) and a Mediterranean stock (SCRS, 1997). In the north Atlantic albacore are taken by surface and longline fisheries. Surface fisheries target juveniles at 50 to 90 cm fork length (FL), and longlines catch sub-adult and adult fish at 60 to120 cm FL. This FMP prohibits the use of driftnet gear and establishes a limited access program for pelagic longline vessels in the U.S. Atlantic tuna fishery. **U.S. Fishery Status:** Fully Fished.

Growth and mortality: The maximum size of albacore has been reported at 127 cm FL (Collette and Nauen, 1983). For both sexes sexual maturity is reached at five years at 90 to 94 cm FL (ICCAT, 1997; Collette and Nauen, 1983). Mortality is higher for females (Collette and Nauen, 1983).

Habitat associations: Albacore tend to aggregate near temperature discontinuities and migrate within water masses; however, they do not seem to cross temperature and oxygen boundaries. Transition zones are preferred over upwelling areas due to the low oxygen content of water in these particular areas (Collette and Nauen, 1983). Albacore schools may also be associated with floating objects, including *Sargassum* (Collette and Nauen, 1983). Habitat associations are summarized in Table 6.3.2.

***Essential Fish Habitat (EFH) for Albacore Tuna (Figure 6-2 a-c)*:**

- **Spawning, eggs and larvae:** At this time, available information is insufficient for the identification of EFH for this life stage within the U.S. EEZ.

- **Juveniles/subadults (<90 cm FL):** In surface waters with temperatures between 15.6° and 19.4° C, offshore the U.S. east coast in the Mid-Atlantic Bight from the 50 m isobath to the 2,000 m isobath with 71° W as the northeast boundary and 38° N as the southwest boundary.

- **Adults (>90 cm FL):** In surface waters with temperatures between 13.5° and 25.2° C, offshore the U.S. eastern seaboard between the 100 and 2,000 m isobaths from southeastern Georges Bank at 41.25° N, south to 36.5° N, offshore the Virginia/North Carolina border; also, in the Blake Plateau and Spur region, from 79° W east to the EEZ boundary and 29° N south to the EEZ boundary.

6.3.1.2 Atlantic Bigeye Tuna (*Thunnus obesus*)

Distribution: Scientific knowledge of Atlantic bigeye tuna is limited. Its range is almost the entire Atlantic from 50° N to 45° S. It is rarely taken in the Gulf of Mexico (W. J. Richards, pers. comm.). Although its distribution with depth in the water column is varied, it is regularly found in deeper waters than are other tuna - to a depth of 250 m. Smaller fish are probably restricted to the tropics, while larger individuals migrate to temperate waters. There is probably one population in the Atlantic (ICCAT, 1997). Young bigeye tuna form schools near the sea surface, mixing with other tuna such as yellowfin and skipjack tuna (Collette and Nauen, 1983).

Predator-prey relationships: The diet of bigeye tuna includes fishes, cephalopods and crustaceans (Dragovich, 1969; Matthews *et al.*, 1977). Predators include large billfishes and toothed whales (Collette and Nauen, 1983).

Life history: Bigeye tuna probably spawn between 15° N and 15° S. A nursery area is known to exist in the Gulf of Guinea (Richards, 1967) off the coast of Africa where larvae have been collected below the 25° C isotherm (Richards and Simmons, 1971). Peak spawning here occurs in January and February, whereas in the northwestern tropical Atlantic spawning occurs in June and July (SCRS, 1978 and 1979). The collection of larvae in U.S. waters has not been confirmed (W. J. Richards, pers. comm.).

Fisheries: The bigeye tuna stock has been exploited by three major gear types - longline, baitboat, and purse seine - and by many countries throughout its range of distribution. ICCAT currently recognizes one stock for management purposes, based on time/area distribution of fish and movements of tagged fish. However, other possibilities such as distinct northern and southern stocks should not be disregarded (SCRS, 1997). This FMP establishes a foundation for negotiating a rebuilding plan at ICCAT for overfished Atlantic bigeye tuna. The FMP also prohibits the use of driftnet gear and establishes a limited access program for pelagic longline vessels in the U.S. Atlantic tuna fishery. **U.S. Fishery Status:** Overfished.

Growth and mortality: Growth rate for bigeye tuna is believed to be rapid. Sexual maturity is attained in the fourth year, at approximately 100 cm FL (SCRS, 1997).

Habitat associations: Juvenile bigeye form schools near the surface, mostly mixed with other tuna such as yellowfin and skipjack. These schools often associate with floating objects, whale sharks and sea mounts (SCRS, 1997). Habitat associations are summarized in Table 6.3.3.

***Essential Fish Habitat (EFH) for Bigeye Tuna (Figure 6-3 a-c)*:**

- **Spawning, eggs and larvae:** At this time, available information is insufficient for the identification of EFH for this life stage within the U.S. EEZ; although it can not be identified as EFH under the Magnuson-Stevens Act because it is located outside the U.S. EEZ, the Gulf of Guinea, off the coast of Africa, is identified as important habitat for spawning adults, eggs and larvae.

- **Juveniles/Subadults (<100 cm FL):** In surface waters from southeastern Georges Bank to the boundary of the EEZ to Cape Hatteras, NC at 35° N from the 200 m isobath to the EEZ boundary; also, in the Blake Plateau region off Cape Canaveral, FL, from 29° N south to the EEZ boundary (28.25° N) and from 79° W east to the EEZ boundary (approximately 76.75° W).

- **Adults (≥100 cm FL):** In pelagic waters from the surface to a depth of 250 m: from southeastern Georges Bank at the EEZ boundary to offshore Delaware Bay at 38° N, from the 100 m isobath to the EEZ boundary; from offshore Delaware Bay south to Cape Lookout, NC (approximately the region off Cape Canaveral, FL), from 29° N south to the EEZ boundary (28.25° N), and from 79° W east to the EEZ boundary (76.75° W).

6.3.1.3 Atlantic Bluefin Tuna (*Thunnus thynnus*)

Distribution: In the western north Atlantic, bluefin tuna range from 45° N to 0° (Collette and Nauen, 1983). However, they have recently been found up to 55° N in the west Atlantic (Vinnichenko, 1996). Bluefin tuna move seasonally from spring (May and June) spawning grounds in the Gulf of Mexico through the Straits of Florida to feeding grounds off the northeast U.S. coast (Mather *et al.*, 1995). It is believed that there is a single stock which ranges from Labrador and Newfoundland south into the Gulf of Mexico and the Caribbean, and also off Venezuela and Brazil. The Labrador Current may separate this western stock from that found in the east Atlantic (ICCAT, 1997; Mather *et al.*, 1995; Tiews, 1963).

From November to January bluefin tuna are concentrated into two separate groups, one in the northwest and the other in the north central Atlantic. In February the central Atlantic aggregation breaks up, with some fish moving southeast to the Azores and some moving southwest (Suda, 1994). Southerly movements from the feeding grounds off the northern United States and wintering areas are not well understood.

A three-way movement among spawning, feeding and wintering areas is assumed for mature fish, and a shorter, two-way feeding-to-wintering movement for juveniles (Mather *et al.*, 1995).

Bluefin tuna distributions are probably constrained by the 12° C isotherm, although individuals can dive to 6° to 8° C waters to feed (Tiews, 1963). Year-to-year variations in movements have been noted (Mather *et al.*, 1995). While bluefin tuna are epipelagic and usually oceanic, they do come close to shore seasonally (Collette and Nauen, 1983). They often occur over the continental shelf and in embayments, especially during the summer months when they feed actively on herring, mackerel and squids in the north Atlantic (Houde, pers. com.). Larger individuals move into higher latitudes than do smaller fish. Bluefin tuna are often found in mixed schools with skipjack tuna, these schools consisting of similarly sized individuals (Tiews, 1963).

Predator-prey relationships: Bluefin tuna larvae initially feed on zooplankton but switch to a piscivorous diet at a relatively small size. Small bluefin tuna larvae prey on other larval fishes, and are subject to the same predators as these larvae, primarily larger fishes and gelatinous zooplankton (McGowan and Richards, 1989). Adults consume squids, pelagic crustaceans, and schooling fishes such as anchovies, sauries and hakes, depending on seasonal prey availability (Collette and Nauen, 1983; Dragovich, 1969, 1970a; Mathews *et al.*, 1977). Predators of adult bluefin tuna include toothed whales, swordfish, sharks and other tuna (especially of smaller individuals) (Tiews, 1963; Chase, 1992).

Life history: Western north Atlantic bluefin tuna spawn from mid-April to mid-June in the Gulf of Mexico and in the Florida Straits (McGowan and Richards, 1989). Although individuals may spawn more than once a year, it is assumed that there is a single annual spawning period. Larvae have been confirmed from the Gulf of Mexico and off the Carolinas (Richards, 1991). Most of the larvae found were located around the 1,000 fathom curve in the northern Gulf of Mexico, with some sporadic collections off Texas. In the Florida Straits they are primarily collected along the western edge of the Florida Current, suggesting active transport from the Gulf of Mexico. This would also explain their occasional collection off the southeast United States. Atlantic bluefin tuna have not been observed spawning (Richards, 1991).

It is not believed that much spawning occurs outside the Gulf of Mexico (Richards, 1991; McGowan and Richards, 1989). Also, it appears that larvae are generally retained in the Gulf until they grow into juveniles; in June, young-of-the-year begin movements in schools to juvenile habitats (McGowan and Richards, 1989) thought to be located over the continental shelf around 34° N and 41° W in the summer and further offshore in the winter. Also, they have been identified from the Dry Tortugas area in June and July (ICCAT, 1997; Richards, 1991). Juveniles migrate to nursery areas located between Cape Hatteras, NC and Cape Cod, MA (Mather, Mason and Jones, 1995).

Fisheries: Atlantic bluefin tuna are caught using a wide variety of gear types, including longlines, purse seines, traps, and various handgears. ICCAT recognizes two management units of Atlantic bluefin, one in the east and one in the west Atlantic; however, some mixing is probably occurring, as fish tagged in one location have been retrieved in the other. These management units are divided as follows: North of 10° N they are separated at 45° W; below the equator they are separated at 25° W, with an eastward shift between those parallels (SCRS, 1997). The effects of reduced stock size on distribution and habitat use is unknown at this time. This FMP implements a 20-year stock rebuilding program for overfished west Atlantic bluefin tuna. The FMP also establishes percentage share domestic allocations for the U.S. Atlantic bluefin tuna fishery, establishes a school size-class (less than 119 cm (47 inches) CFL) “reserve” category, and closes an area of the northwest Atlantic to pelagic longline fishing in June in order to reduce discards of bluefin tuna. **U.S. Fishery Status:** Overfished.

Growth and mortality: Bluefin tuna can grow to more than 650 kg in weight and 300 cm in length, with no apparent difference between the growth rates of males and females (Mather *et al*., 1995). Maximum age is estimated to be more than 20 years, with sexual maturity reached at approximately 196 cm (77 inches) FL and a weight of approximately 145 kg (320 lbs). This size is believed to be reached in the west Atlantic at eight years, as opposed to five years in the east Atlantic. Not only do bluefin tuna in the west Atlantic mature more slowly than those in the east Atlantic, but they also are believed to grow more slowly and reach a larger maximum size (SCRS, 1997). The rapid larval growth rate is estimated as one mm/day up to 15 mm, the size at transformation (McGowan and Richards, 1989).

Habitat associations: It is believed that there are probably certain features of the bluefin tuna larval habitat in the Gulf of Mexico which determine growth and survival rates, and that these features show variability from year to year, perhaps accounting for a significant portion of the fluctuation in yearly recruitment success (McGowan and Richards, 1989). The habitat requirements for larval success are not known, but larvae are collected within narrow ranges of temperature and salinity - approximately 26° C and 36 ppt. Along the coast of the southeastern United States onshore meanders of the Gulf Stream can produce upwelling of nutrient rich water along the shelf edge. In addition, compression of the isotherms on the edge of the Gulf Stream can form a stable region which, together with the upwelled nutrients, provides an area favorable to maximum growth and retention of food for the larvae (McGowan and Richards, 1989). Size classes used for habitat analysis for bluefin tuna are based on the sizes at which they shift from a schooling behavior to a more solitary existence. Bluefin have traditionally been grouped by “small schooling,” “large schooling,” “giant,” etc. Future analyses should more fully evaluate habitat differences between the traditional size classes if the data are available. Habitat associations are summarized in Table 6.3.4.

***Essential Fish Habitat for Atlantic Bluefin Tuna (Figure 6-4 a-d)*:**

- **Spawning, eggs and larvae:** In pelagic and near coastal surface waters from the North Carolina/South Carolina border at 33.5° N, south to Cape Canaveral, FL from 15 miles from shore to the 200 m isobath; all waters from offshore Cape

Canaveral at 28.25° N south around peninsular Florida to the U.S./Mexico border from 15 miles from shore to the EEZ boundary.

- **Juveniles/Subadults (<145 cm TL):** All inshore and pelagic surface waters warmer than 12° C of the Gulf of Maine and Cape Cod Bay, MA from Cape Ann, MA (~42.75° N) east to 69.75° W (including waters of the Great South Channel west of 69.75° W), continuing south to and including Nantucket Shoals at 70.5° W to off Cape Hatteras, NC (approximately 35.5° N), in pelagic surface waters warmer than 12° C, between the 25 and 200 m isobaths; also in the Florida Straits, from 27° N south around peninsular Florida to 81° W in surface waters from the 200 m isobath to the EEZ boundary.

- **Adults (>145 cm TL):** In pelagic waters of the Gulf of Maine from the 50 m isobath to the EEZ boundary, including the Great South Channel, then south of Georges Bank to 39° N from the 50 m isobath to the EEZ boundary; also, south of 39° N, from the 50 m isobath to the 2,000 m isobath to offshore Cape Lookout, NC at 34.5° N. In pelagic waters from offshore Daytona Beach, FL (29.5° N) south to Key West (82° W) from the 100 m isobath to the EEZ boundary; in the Gulf of Mexico from offshore Terrebonne Parish, LA (90° W) to offshore Galveston, TX (95° W) from the 200 m isobath to the EEZ boundary.

6.3.1.4 Atlantic Skipjack Tuna (*Katsuwonus pelamis*)

Distribution: Skipjack tuna are circumglobal in tropical and warm-temperate waters, generally limited by the 15° C isotherm. In the west Atlantic skipjack range as far north as Newfoundland (Vinnichenko, 1996) and as far south as Brazil (Collette and Nauen, 1983). Skipjack tuna are an epipelagic and oceanic species and may dive to a depth of 260 m during the day. Skipjack tuna is also a schooling species, forming aggregations associated with hydrographic fronts (Collette and Nauen, 1983). There has been no trans-Atlantic recovery of tags; eastern and western stocks are considered separate (ICCAT, 1997).

Predator-prey relationships: Skipjack tuna is an opportunistic species which preys upon fishes, cephalopods and crustaceans (Dragovich, 1969, 1970b; Dragovich and Potthoff, 1972; ICCAT, 1997; Collette and Nauen, 1983). Predators include other tuna and billfishes (Collette and Nauen, 1983). Skipjack tuna are believed to feed in surface waters down to a depth of five meters. Stomach contents often include *Sargassum* or *Sargassum* associated species (Morgan *et al.*, 1985).

Life history: Skipjack tuna spawn opportunistically in equatorial waters throughout the year, and in subtropical waters from spring to early fall (Collette and Nauen, 1983). Larvae have been collected off the east coast of Florida from October to December (Far Seas Fisher. Res. Lab., 1978) and in the Gulf of Mexico and Florida Straits from June to October (Houde, pers. comm.). However, most spawning takes place during summer months in the Caribbean, off Brazil (with the peak in January through March), in the Gulf of Mexico (April to May), and in the Gulf of Guinea (throughout the year) (SCRS, 1978/79; Richards, 1967).

Fisheries: This fishery is almost exclusively a surface gear fishery, although some skipjack tuna are taken as longline bycatch. Most skipjack tuna are taken in the east Atlantic and off the coast of Brazil, most recently with the use of floating objects to attract them. ICCAT assumes two management units for this species (eastern and western) due to the development of fisheries on both sides of the Atlantic and to the lack of transatlantic tag recoveries. This FMP prohibits the use of driftnet gear and establishes a limited access program for pelagic longline vessels in the U.S. Atlantic tuna fishery. **U.S. Fishery Status:** Fully Fished.

Growth and mortality: Maximum size of the species is reported at 108 cm FL and a weight of 34.5 kg. Size at sexual maturity is 45 cm (18 inches.) for males and 42 cm for females. This size is believed to correspond to about 1 to 1.5 years of age, although significant variability in interannual growth rates make size-to-age relationships difficult to estimate (ICCAT, 1997; Collette and Nauen, 1983). Growth rate is variable and seasonal, with individuals from the tropical zone having a higher growth rate than those from the equatorial zone (SCRS, 1997). Life span is estimated to be eight to 12 years (Collette and Nauen, 1983).

Habitat associations: Aggregations of skipjack tuna are associated with convergences and other hydrographic discontinuities. Also, skipjack tuna associate with birds, drifting objects, whales, sharks and other tuna species (Colette and Nauen, 1983). The optimum temperature for the species is 27° C, with a range from 20° to 31° C (ICCAT, 1995). Habitat associations are summarized in Table 6.3.5.

***Essential Fish Habitat (EFH) for Skipjack Tuna (Figure 6-5 a-d)*:**

- **Spawning, eggs and larvae:** In offshore waters, from the 200 m isobath out to the EEZ boundary, from 28.25° N south around peninsular Florida and the Gulf Coast to the U.S./Mexico border.

- **Juveniles/subadults (<45 cm FL):** In pelagic surface waters from 20° to 31° C in the Florida Straights off southeastern Florida, from the 25 m isobath to the 200 m isobath, from 27.25° N south to 24.75° N southwest of the coast of Key Largo, FL.

- **Adults (> 45 cm FL):** In pelagic surface waters from 20° to 31° C in the Mid-Atlantic Bight, from the 25 m isobath to the 200 m isobath, from 71° W, off the coast of Martha's Vineyard, MA, south and west to 35.5° N, offshore Oregon Inlet, NC.

6.3.1.5 Atlantic Yellowfin Tuna (*Thunnus albacares*)

Distribution: Atlantic yellowfin tuna are circumglobal in tropical and temperate waters. In the west Atlantic they range from 45° N to 40° S. Yellowfin tuna is an epipelagic, oceanic species, found in water temperatures between 18° and 31° C. It is a schooling species, with juveniles found in schools at the surface, mixing with skipjack and bigeye tuna. Larger fish are found in deeper water and also extend their ranges into higher latitudes. All individuals in the Atlantic probably comprise a single population, although movement patterns are not well known (SCRS, 1997; Collette and Nauen, 1983). There are possible movements of fish spawned in the Gulf of Guinea to more coastal waters off Africa, followed by movements toward the U.S. coast, at which time they reach a length of 60 to 80 cm (ICCAT, 1977). In the Gulf of Mexico yellowfin tuna occur beyond the 500 fathom isobath (Idyll and de Sylva, 1963).

Predator-prey relationships: Atlantic yellowfin tuna are opportunistic feeders. Stomachs have been found to contain a wide variety of fish and invertebrates (Dragovich, 1969, 1970b; Dragovich and Potthoff, 1972; Matthews *et al.*, 1977). Stomach contents of yellowfin from St. Lucia and the Caribbean contained squid and the larvae of stomatopods, crabs and squirrelfish (Idyll and de Sylva, 1963). Stomach contents often contain *Sargassum* or *Sargassum* associated fauna. Yellowfin tuna are believed to feed primarily in surface waters down to a depth of 100 m (Morgan *et al.*, 1985).

Life history: Spawning occurs throughout the year in the core areas of the species' distribution - between 15° N and 15° S - and also in the Gulf of Mexico and the Caribbean, with peaks occurring in the summer (ICCAT, 1994; Richards, pers. comm.). Yellowfin tuna are believed to be multiple spawners (Houde, pers. comm.), and larval distribution appears to be limited to water temperatures above 24° C and salinity greater than 33 ppt (Richards and Simmons, 1971). Larvae have been collected near the Yucatan peninsula, and during September in the northern Gulf of Mexico along the Mississippi Delta (ICCAT, 1994).

Fisheries: Yellowfin tuna are caught by surface gears (purse seine, baitboat, troll, and handline) and with sub-surface gears (longline). A single stock is assumed for the Atlantic, based on transatlantic tag recaptures, time/area size frequency distribution, etc. (SCRS, 1997). For U.S. fishermen this FMP establishes a three-fish-per-person-per-day recreational retention limit for yellowfin tuna. The FMP also prohibits the use of driftnet gear and establishes a limited access program for pelagic longline vessels in the U.S. Atlantic tuna fishery. **U.S. Fishery Status:** Fully Fished.

Growth and mortality: The maximum size of yellowfin tuna is over 200 cm FL (Collette and Nauen, 1983). Sexual maturity is reached after at about three years of age, at 110 cm FL and a weight of 25 kg. Although it is not known if there is a differential growth rate between males and females (ICCAT, 1994), males are predominant in catches of larger sized fish (SCRS, 1997). Natural mortality is 0.8 for fish less than 65 cm in length, and 0.6 for fish greater than 65 cm. Mortality is higher for females of this size (ICCAT, 1994).

Habitat associations: Adult yellowfin tuna are confined to the upper 100 m of the water column due to their intolerance of oxygen concentrations of less than 2 ml/l (Collette and Nauen, 1983). Association with floating objects has been observed, and in the Pacific larger individuals often school with porpoises (Collette and Nauen, 1983). Juveniles are found nearer to shore than are adults (SCRS, 1994). In the Gulf of

Mexico adults usually occur 75 km or more offshore, while in the Caribbean they are found closer to shore. Although there appears to be a year-round population in the southern part of the Gulf of Mexico (Idyll and de Sylva, 1963), in June there appears to be some movement from this region to the northern part, resulting in greater catches there from July to December. Habitat associations are summarized in Table 6.3.6.

***Essential Fish Habitat (EFH) for Yellowfin Tuna (Figure 6-6 a-d)*:**

- **Spawning, eggs and larvae:** In offshore waters, from the 200 m isobath out to the EEZ boundary, from 28.25° N south around peninsular Florida and the Gulf Coast to the U.S./Mexico border, especially associated with the Mississippi River plume and the Loop Current. Also, all U.S. waters in the Caribbean from the 200 m isobath to the EEZ boundary.

- **Juveniles/subadults (<110 cm FL):** Pelagic waters from the surface to 100 m deep between 18° and 31° C from offshore Cape Cod, MA (70° W) southward to Jekyll Island, GA (31° N), between 500 and 2,000 m; off Cape Canaveral, FL from 29° N south to the EEZ boundary (approximately 28.25° N) and from 79° W east to the EEZ boundary (approximately 76.75° W); in the Gulf of Mexico from the 200 m isobath to the EEZ boundary.

- **Adults (> 110 cm FL):** (Identical to juveniles/subadults EFH): Pelagic waters from the surface to 100 m deep between 18° and 31° C from offshore Cape Cod, MA (70° W) southward to Jekyll Island, GA (31° N), between 500 and 2,000 m; off Cape Canaveral, FL from 29° N south to the EEZ boundary (approximately 28.25° N) and from 79° W east to the EEZ boundary (approximately 76.75° W); in the Gulf of Mexico from the 200 m isobath to the EEZ boundary.

6.3.2 Swordfish (*Xiphias gladius*)

Distribution: Swordfish are circumglobal, ranging through tropical, temperate and sometimes cold water regions. Their latitudinal range is from 50° N to 40-45° S in the west Atlantic, and 60° N to 45-50° S in the east Atlantic (Nakamura, 1985). The species moves from spawning grounds in warm waters to feeding grounds in colder waters. In the western north Atlantic two movement patterns are apparent: some fish move northeastward along the edge of the U.S. continental shelf in summer and return southwestward in autumn; another group moves from deep water westward toward the continental shelf in summer and back into deep water in autumn (Palko *et al.*, 1981). Swordfish are epipelagic to meso-pelagic, and are usually found in waters warmer than 13° C. Their optimum temperature range is believed to be 18° to 22° C but they will dive into 5° to10° C waters at depths of up to 650 m (Nakamura, 1985). Swordfish migrate diurnally, coming to the surface at night (Palko *et al.*,1981). Carey (1990, in Arocha, 1997) observed different diel migrations in two groups of fish: swordfish in neritic (shallow, near-coastal) waters of the northwest Atlantic were found in bottom waters during the day and moved to offshore surface waters at night. Swordfish in oceanic waters migrated vertically from a daytime depth of 500 m to 90 m at night.

Predator-prey relationships: Adult swordfish are opportunistic feeders, having no specific prey requirements. They feed at the bottom as well as at the surface, in both shallow and deep waters. In waters greater than 200 m deep they feed primarily on pelagic fishes including small tunas, dolphinfishes, lancetfish (*Alepisaurus*), snake mackerel (*Gempylus*), flyingfishes, barracudas and squids such as *Ommastrephes*, *Loligo*, and *Illex*. In shallow water they prey upon neritic fishes, including mackerels, herrings, anchovies, sardines, sauries, and needlefishes. In deep water swordfish may also take demersal fishes such as hakes, pomfrets (Bromidae), snake mackerels, cutlass fish (trichiurids), lightfishes (Gonostomatidae), hatchet fishes (Sternoptychidae), redfish, lanternfishes, and cuttlefishes (Nakamura, 1985).

In the Gulf of Mexico swordfish were found to feed primarily on cephalopods - 90 percent of stomach contents consisted of 13 species of teuthoid squids, most of which were *Illex*, and two species of octopus (Toll and Hess, 1981). Stillwell and Kohler (1985) found that 80 percent of the stomach contents of swordfish taken off the northeast coast of the United States consisted of cephalopods, of which short-finned squid (*Illex illecebrosus*) made up 26.4 percent. Adult swordfish in neritic waters will feed inshore near the bottom during the daytime and head seaward to feed on cephalopods at night. The movement of larger individuals into higher latitudes in the summer and fall may be in-part to allow those individuals access to high concentrations of *Illex* (Arocha, 1997). Predators of adult swordfish are probably restricted to sperm whales (*Physeter catodon*), killer whales (*Orcinus orca*) and large sharks such as mako (*Isurus* spp).

Typically, swordfish larvae less than 9.0 mm in length consume small zooplankton, those 9.0 to 14.0 mm feed on mysids, phyllopods and amphipods, and at sizes greater than 21 mm they begin to feed on the larvae of other fishes. Juveniles feed on squids, fishes and some pelagic crustaceans (Palko *et al.*, 1981). Larvae are preyed upon by other fishes, and juveniles fall prey to predatory fishes, including sharks, tunas, billfishes, and adult swordfish (Palko *et al.*, 1981).

Life history: First spawning for north Atlantic swordfish occurs at four to five years of age (74 kg) in females. Fifty percent maturity in females is reached at 179 to 182 cm LJFL, and in males at 112 to 29 cm LJFL (21 kg) at approximately 1.4 years of age (Arocha, 1997; Nakamura, 1985; Palko *et al.*, 1981). Most spawning takes place in waters with surface temperatures above 20° to 22° C, between 15° N and 35° N (Arocha, 1997; Palko *et al.*, 1981). In the western north Atlantic spawning occurs in distinct locations at different times of the year: south of the Sargasso Sea and in the upper Caribbean spawning occurs from December to March, while off the southeast coast of the United States it occurs from April through August (Arocha, 1997). Major spawning grounds are probably located in the Straits of Yucatan and the Straits of Florida (Grall *et al.*, 1983). Larvae have been found in largest abundance from the Straits of Florida to Cape Hatteras, NC and around the Virgin Islands. Larvae are associated with surface temperatures between 24° and 29° C. The Gulf of Mexico is believed to serve as a nursery area (Palko *et al.*, 1981). Grall *et al.* (1983) found larvae ten mm and larger to be abundant in the Caribbean, the Straits of Florida and the Gulf Stream north of Florida from December to February. In the western Gulf of Mexico, large larvae were found from March to May and from September to November; many larvae of all sizes were collected in the Caribbean and were also present year-round in the eastern Gulf of Mexico, the Straits of Florida and the Gulf Stream. Juvenile fish are frequently caught in the pelagic longline fishery in the Gulf of Mexico, the Atlantic coast of Florida, and near the Charleston Bump, regions that may serve as nurseries for north Atlantic swordfish (Cramer and Scott, 1998).

Fisheries: Swordfish in the Atlantic are taken by a directed longline fishery and as bycatch of the tuna longline fishery. There are also seasonal harpooning and driftnetting efforts off Nova Scotia (harpooning), off the northeast U.S. coast, and on the Grand Banks (driftnetting) (Arocha, 1997). The effect of this reduction in stock size on habitat use and species distributions is unknown. In January 1999, NMFS prohibited the use of driftnets for the swordfish fishery. In March 1999, NMFS instituted a program requiring all swordfish imported into the United States to have a certificate of eligibility specifying the origin of the fish. If the swordfish is from the Atlantic it must meet the 33-lb dw minimum size requirement of ICCAT. This FMP implements limited access for this fishery. **U.S. Fishery Status:** Overfished.

Growth and mortality: Swordfish reach a maximum length of 445 cm total length (TL) and a maximum weight of 540 kg. Males and females have different growth rates, with females longer and heavier at any given age (Nakamura, 1985). Natural mortality rate was estimated at 0.21 to 0.43 by Palko *et al.* (1981), but ICCAT presently uses an estimate of 0.2 (Arocha, 1997). Berkeley and Houde (1981) found a higher growth rate for females than males over two years of age, and also found males to have a higher mortality rate than females.

Habitat associations: In the winter in the north Atlantic, swordfish are restricted to the warmer waters of the Gulf Stream, while in the summer their distribution covers a larger area. Distribution is size and temperature related, with few fish under 90 kg found in waters with temperatures less than 18° C. Larvae are restricted to a narrow surface temperature range, and are distributed throughout the Gulf of Mexico, in areas of the Caribbean, and in the Gulf Stream along the U.S. coast as far north as Cape Hatteras, NC. Concentrations of adult swordfish seem to occur at ocean fronts between water masses associated with boundary currents, including the Gulf Stream and Loop Current of the Gulf of Mexico (Arocha, 1997). Habitat associations are summarized in Table 6.3.7.

***Essential Fish Habitat for Atlantic Swordfish (Figure 6-7 a-d)*:**

- **Spawning, eggs and larvae:** From offshore Cape Hatteras, NC (approximately 35° N) extending south around peninsular Florida through the Gulf of Mexico to the U.S./Mexico border from the 200 m isobath to the EEZ boundary; associated with the Loop Current boundaries in the Gulf and the western edge of the Gulf Stream in the Atlantic; also, all U.S. waters of the Caribbean from the 200 m isobath to the EEZ boundary.

- **Juveniles/subadults (≤180 LJFL):** In pelagic waters warmer than 18° C from the surface to a depth of 500 m, from offshore Manasquan Inlet, NJ at 40° N, east to 73° N, and south to the waters off Georgia at 31.5° N, between the 25 and 2,000 m isobaths; offshore Cape Canaveral, FL (approximately 29° N) extending from the 100 m isobath to the EEZ boundary (south and east) around peninsular Florida; in the Gulf of Mexico from Key West to offshore Galveston, TX (95° W) from the 200 m isobath to the EEZ boundary, with the exception of the area between 86° W and 88.5° W, where the seaward boundary of EFH is the 2,000 m isobath.

- **Adults (>180 LJFL):** In pelagic waters warmer than 13° C from the surface to 500 m deep, offshore the U.S. east and Gulf coasts from the intersection of the 100 m isobath and the EEZ boundary southeast of Cape Cod, MA to south and offshore Biscayne Bay, FL at 25.5° N, from the 100 to 2,000 m isobath or the EEZ boundary, which ever is closer to land; from offshore Tampa Bay, FL at 85° N to offshore Mobile Bay, AL at 88° N between the 200 and 2,000 m isobaths; from offshore south of the Mississippi River delta, 89° N to offshore waters south of Galveston, TX, 95° N from the 200 m isobath to the EEZ boundary.

6.3.3 Large Coastal Sharks [4] (U.S. Fishery Status: Overfished)

6.3.3.1 Basking Sharks

Basking shark (*Cetorhinus maximus*). The basking shark is the second largest fish in the world, its size exceeded only by the whale shark. Like the whale shark, it is a filter-feeding plankton eater. It is a migratory species of the subpolar and cold temperate seas throughout the world, spending the summer in high latitudes and moving into warmer water in winter (Castro, 1983). In spite of its size and local abundance in summer, its habits are very poorly known. Sims and Quayle (1998) have shown that basking sharks forage along thermal fronts and seek the highest densities of zooplankton. During the European autumn basking sharks disappear and are not seen until the following summer, when they return after giving birth. Habitat associations are summarized in Table 6.3.8.

Reproductive potential: Little is known about basking shark reproductive processes. Males are believed to reach maturity between 460 and 610 cm (Bigelow and Schroeder, 1948), at an estimated age of four to five years (Parker and Stott, 1965). However, these age estimates have not been validated. Females mature at 810 to 980 cm (Compagno, 1984). It is believed that female basking sharks give birth to young measuring about 180 cm total length (TL), probably in high latitudes. There are no modern reports on the size of litters or data on reproductive cycles.

Impact of fisheries: Fishing for the basking shark is prohibited in U.S. waters, although basking sharks are common off the east coast in winter.

***Essential Fish Habitat for Basking Shark (Figure 6-8 a-c)*:**

- **Neonate/early juveniles (≤270 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults (271 to 810 cm TL):** Offshore the mid-Atlantic United States south of Nantucket Shoals at 70° W to the north edge of Cape Hatteras, NC at 35.5° N in waters 50 to 200 m deep; associated with boundary conditions created by the western edge of the Gulf Stream.

- **Adults (≥810 cm TL):** Offshore southern New England, west of Nantucket Shoals at 70° W to Montauk, Long Island, NY at 72° W, out to the continental

[4] The majority of the information included in this and the follow sections of shark life histories was provided by Dr. José I. Castro from the following publication: Castro, Jose I, Christa M. Woodley, and Rebecca L. Brudek. Status of shark species. unpublished manuscript to be published by FAO in 1999. 89 pp. Additional information has been added or modified in this chapter as appropriate to meet the objectives of this FMP.

shelf in waters 50 to 200 m deep, where water column physical conditions create high abundances of zooplankton.

6.3.3.2 Hammerhead Sharks

Great hammerhead (*Sphyrna mokarran*). This shark found both in open oceans and shallow coastal waters. One of the largest sharks, the great hammerhead is circum-tropical in warm waters (Castro, 1983). It is usually a solitary fish, unlike the more common scalloped hammerhead which often forms very large schools. Habitat associations are summarized in Table 6.3.9.

Reproductive potential: In Australian waters males mature at about 210 to 258 cm TL and females mature usually at 210 to 220 cm TL (Stevens and Lyle, 1989). Pups measure about 67 cm TL at birth (Stevens and Lyle, 1989) and litters consist of 20 to 40 pups (Castro, 1983). The gestation period lasts about 11 months (Stevens and Lyle, 1989). The reproductive cycle is biennial (Stevens and Lyle 1989). There are few reports and little data on its nurseries. Hueter (CSR data) found small juveniles from Yankeetown, FL to Charlotte Harbor, FL from May to October at temperature of 23.9 to 28.9°C, and salinities of 21.9 to 34.2 ppt.

Impact of fisheries: Great hammerheads are caught in coastal longline shark fisheries as well as in pelagic tuna and swordfish longline fisheries. Its fins bring the highest prices in the shark fin market. Although finning is prohibited in the Atlantic, in many fishing operations elsewhere the fins are removed while the carcasses are discarded at sea. The great hammerhead is vulnerable to overfishing because of its biennial reproductive cycle, and because it is caught both in directed fisheries and as bycatch in tuna and swordfish fisheries.

***Essential Fish Habitat for Great Hammerhead (Figure 6-9 a-c)*:**

- **Neonate/early juveniles (≤70 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults (71 to 220 cm TL):** Off the Florida coast, all shallow coastal waters out to the 100 m isobath from 30° N south around peninsular Florida to 82.5° W, including Florida Bay and adjacent waters east of 81.5° W (north of 25° N), and east of 82.5° W (south of 25° N)

- **Adults (≥221 cm TL):** Off the entire east coast of Florida, all shallow coastal waters out to the 100 m isobath, south of 30° N, including the west coast of Florida to 85.5° W.

Scalloped hammerhead (*Sphyrna lewini*). This is a very common, large, schooling hammerhead of warm waters. It is the most common hammerhead in the tropics and is readily available in abundance to inshore artisanal and small commercial fisheries as well as offshore operations (Compagno, 1984). It migrates seasonally north-south along the eastern United States. Habitat associations are summarized in Table 6.3.10.

Reproductive potential: Males in the Atlantic mature at about 180 to 185 cm TL (Bigelow and Schroeder, 1948), while those in the Indian Ocean mature at 140 to 165 cm TL (Bass *et al.*, 1973). Females mature at about 200 cm TL (Stevens and Lyle, 1989). The young are born at 38 to 45 cm TL, litters consisting of 15 to 31 pups (Compagno, 1984). The reproductive cycle is annual (Castro, 1993b) and the gestation period is nine to ten months (Stevens and Lyle, 1989). Castro (1993b) found nurseries in the shallow coastal waters of South Carolina; Hueter (CSR data) found small juveniles from Yankeetown to Charlotte Harbor on the west coast of Florida, in temperatures of 23.2° to 30.2 ° C, salinities of 27.6 to 36.3 ppt, and DO of 5.1 to 5.5 ml/l.

Impact of fisheries: Because the scalloped hammerhead forms very large schools in coastal areas, it is targeted by many fisheries for its high priced fins. Castro *et al*. (in prep.) consider the scalloped hammerhead vulnerable to overfishing because its schooling habit makes it extremely vulnerable to gillnet fisheries, and because scalloped hammerheads are actively pursued in many fisheries throughout the world.

***Essential Fish Habitat for Scalloped Hammerhead (Figure 6-10 a-e)*:**

- **Neonate/early juveniles (≤45 cm TL):** Shallow coastal waters of the South Atlantic Bight, off the coast of South Carolina, Georgia, and Florida, west of 79.5° W and north of 30° N, from the shoreline out to 25 miles offshore. Additionally, as displayed on Figure 6-10e: shallow coastal bays and estuaries less than 5 m deep, from Apalachee Bay to St. Andrews Bay, FL.

- **Late juveniles/subadults (46 to 249 cm TL):** All shallow coastal waters of the U.S. Atlantic seaboard from the shoreline to the 200 m isobath from 39° N, south to the vicinity of the Dry Tortugas and the Florida Keys at 82° W; also in the Gulf of Mexico, in the area of Mobile Bay, AL and Gulf Islands National Seashore, all shallow coastal waters from the shoreline out to the 50 m isobath.

- **Adults (≥250cm TL):** In the South Atlantic Bight from the 25 to 200 m isobath from 36.5° N to 33° N, then continuing south from the 50 m isobath offshore to the 200 m isobath to 30° N, then from the 25 m isobath to the 200 m isobath from 30° N south to 28° N; also, in the Florida Straights between the 25 and 200 m isobaths, from 81.5° W west to 82.25° W in the vicinity of Key West and the Dry Tortugas.

Smooth hammerhead (*Sphyrna zygaena*). This is an uncommon hammerhead of temperate waters. Fisheries data for hammerheads includes this species and the scalloped and great hammerheads; however, there is little data specific to the species. Habitat associations are summarized in Table 6.3.11.

Essential Fish Habitat for Smooth Hammerhead (Figure 6-11a):

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.3.3 Mackerel Sharks

White shark (*Carcharodon carcharias*). The white shark is the largest of the lamnid, or mackerel, sharks. It is a poorly known apex predator found throughout temperate, subtropical and tropical waters. Its presence is usually sporadic throughout its range, although there are a few localities (e.g., off California, Australia, and South Africa) where it is seasonally common. Large adults prey on seals and sea lions, and are sometimes found around their rookeries. The white shark is also a scavenger of large dead whales. It has been described as the most voracious of the fish-like vertebrates and has been known to attack bathers, divers, and even boats. Habitat associations are summarized in Table 6.3.12.

Reproductive potential: Very little is known of its reproductive processes because only two gravid females have been examined by biologists in modern times. Both specimens contained seven embryos. Recent observations show that white sharks carry seven to ten embryos that are born at 120 to 150 cm TL (Uchida *et al.*, 1996; Francis, 1996). The lengths of the reproductive and gestation cycles are unknown. White sharks are believed to mature at between 370 and 430 cm at an estimated age of nine to ten years (Cailliet *et al.*, 1985). Cailliet *et al.* (1985) estimated growth rates of 25.0 to 30.0 cm/year for juveniles and 21.8 cm/year for older specimens, and gave the following von Bertalanffy parameters: n = 21, L_∞ = 763.7 cm, K = 0.058, t_o = -3.53. They estimated that a 610 cm TL specimen would be 13 to 14 years old. The types of habitats and locations of nursery areas are unknown. It is likely that the nurseries will be found in the warmer parts of the range in deep water.

Impact of fisheries: The white shark is a prized game fish because of its size. It is occasionally caught in commercial longlines or in near-shore drift gillnets, but it must be released in a manner which maximizes its survival. Its jaws and teeth are often seen in specialized markets where they bring high prices. Preliminary observations (Strong *et al.*, 1992) show that populations may be small, highly localized, and very vulnerable to overexploitation. The white shark has been adopted as a symbol of a threatened species by some conservation organizations, and has received protected status in South Africa, Australia, and the State of California. In 1997, the Unites States implemented a catch and release only recreational fishery for the white shark, while prohibiting possession of the species. There are no published population assessments, or even anecdotal reports, indicating any population decreases of the white shark. Nevertheless, it is a scarce apex predator and a long-lived species of a limited reproductive potential that is vulnerable to longlines.

***Essential Fish Habitat (EFH) for White Shark (Figure 6-12 a-b)*:**

- **Neonate/early juveniles (≤175 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults (175 to 479 cm TL):** Offshore northern New Jersey and Long Island, NY in pelagic waters from the 25 to 100 m isobath in the New York Bight area, bounded to the east at 71.5° W and to the south at 39.5° N; also, offshore Cape Canaveral, FL between the 25 and 100 m isobaths from 29.5° N south to 28° N.

- **Adults (≥480cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.3.4 Nurse Sharks (nurse sharks may also be classified into the family of carpet sharks along with the whale shark)

Nurse shark (*Ginglymostoma cirratum*). The nurse shark inhabits littoral waters in both sides of the tropical and subtropical Atlantic, ranging from tropical West Africa and the Cape Verde Islands in the east, and from Cape Hatteras, NC to Brazil in the west. It is also found in the east Pacific, ranging from the Gulf of California to Panama and Ecuador (Bigelow and Schroeder, 1948). It is a shallow water species, often found lying motionless on the bottom under coral reefs or rocks. It often congregates in large numbers in shallow water (Castro, 1983). Habitat associations are summarized in Table 6.3.13.

Reproductive potential: The nurse shark matures at about 225 cm TL (Springer 1938). Litters consist of 20 to 30 pups, the young measuring about 30 cm TL at birth. The gestation period is about five to six months and reproduction is biennial (Castro, unpubl.). The age at maturity is unknown, but the nurse shark is a long-lived species - Clark (1963) reported an aquarium specimen living up to 24 years in captivity. Its nurseries are in shallow turtle grass (*Thalassia*) beds and shallow coral reefs (Castro, unpubl.). However, juveniles are also found around mangrove islands in south Florida. Hueter (CSR data) found numerous juveniles along the west coast of Florida, in temperatures of 17.5° to 32.1° C, salinities of 28.5 to 35.1 ppt, and DO of 4.7 to 97 ml/l. Large numbers of nurse sharks often congregate in shallow waters of the Florida Keys and the Bahamas at mating time in June and July (Fowler, 1906; Gudger, 1912). A small area has been set up for protection of mating sharks at Fort Jefferson in the Dry Tortugas. It is not certain, however, whether this area is a primary mating ground or a refuge for mated females.

Impact of fisheries: In North America and the Caribbean the nurse shark has often been pursued for its hide, which is said to be more valuable than that of any other shark (Springer, 1950a). The fins have no value and the meat is of questionable value (Springer, 1979).

***Essential Fish Habitat for Nurse Shark (Figure 6-13 a-d)*:**

- **Neonate/early juveniles (≤60 cm TL):** Shallow coastal areas from West Palm Beach, FL south to the Dry Tortugas in waters less than 25 m deep.

- **Late juveniles/subadults (61 to 225 cm TL):** Shallow coastal waters from the shoreline to the 25 m isobath off the east coast of Florida from south of Cumberland Island, GA (at 30.5° N) to the Dry Tortugas; also shallow coastal waters from Charlotte Harbor, FL (at 26° N) to the north end of Tampa Bay, FL (at 28° N); also, off southern Puerto Rico, shallow coastal waters out to the 25 m isobath from 66.5° W to the southwest tip of the island.

- **Adults (≥226cm TL):** (Identical to EFH for Late juveniles/Subadults): Shallow coastal waters from the shoreline to the 25 m isobath off the east coast of Florida from south of Cumberland Island, GA (at 30.5° N) to the Dry Tortugas; also shallow coastal waters from Charlotte Harbor, FL (at 26° N) to the north end of Tampa Bay, FL (at 28° N); also, off southern Puerto Rico, shallow coastal waters out to the 25 m isobath from 66.5° W to the southwest tip of the island.

6.3.3.5 Requiem Sharks

Bignose shark (*Carcharhinus altimus*). The bignose shark is a poorly known, bottom dwelling shark of the deeper waters of the continental shelves. It is found in tropical and subtropical waters throughout the world (Castro, 1983). Habitat associations are summarized in Table 6.3.14.

Reproductive potential: The smallest mature specimens recorded by Springer (1960) were a 213 cm TL male and a 221 cm TL female. Springer (1950c) reported litters of seven to eight pups, while Stevens and McLoughlin (1991) noted from three to 15 pups. Birth size is probably around 70 cm TL based on the largest embryos (65 to 70 cm TL) reported by Fourmanoir (1961) and free swimming specimens with fresh umbilical scars seen by Bass *et al.* (1973). The lengths of the gestation period and of the breeding cycle have not been reported. The location of the nurseries is unknown.

Impact of fisheries: Springer (1950c) stated that the bignose shark appeared to be the most common large shark of the edges of the continental shelves in the West Indian region, and that the species made up a substantial portion of the catch in the Florida shark fishery of the1940s. In some areas bignose sharks are mistaken for sandbar sharks. This FMP prohibits possession of bignose sharks as a precautionary measure to ensure that directed fisheries and/or markets do not develop pending additional stock assessments.

Essential Fish Habitat for Bignose Shark (Figure 6-14 a-c):

- **Neonate/early juveniles (≤155 cm TL):** From offshore the Delmarva Peninsula at 38° N, to offshore Bull's Bay, SC at 32° N, between the 100 and 200 m isobaths.

- **Late juveniles/subadults (156 to 220 cm TL):** From offshore the Delmarva Peninsula at 38° N, to offshore Bull's Bay, SC at 32° N, between the 100 and 500 m isobaths; also, from St. Augustine, FL at 30° N, south to offshore West Palm Beach, FL at 27° N, between the 100 and 500 m isobaths.

- **Adults (≥221 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

Blacktip shark (*Carcharhinus limbatus*). The blacktip shark is circumtropical in shallow coastal waters and offshore surface waters of the continental shelves. In the southeastern United States it ranges from Virginia to Florida and the Gulf of Mexico. Garrick (1982), on examining a large number of museum specimens, believed it to be a single worldwide species. Dudley and Cliff (1993a), working off South Africa, and Castro (1996), working on blacktip sharks off the southeastern United States, showed that there were significant differences among the various populations. The blacktip shark, or "blacktip" is a fast moving shark that is often seen at the surface, frequently leaping and spinning out of the water. It often forms large schools that migrate seasonally north-south along the coast. This species is much sought after in the eastern United States because of the quality of its flesh. The blacktip and the sandbar shark are the two species of greatest importance to the commercial fisheries in that region. In the markets of the United States "blacktip" has become synonymous with good quality shark; therefore, many other species are also sold under that name. Habitat associations are summarized in Table 6.3.15.

Reproductive potential: Off the southeastern United States males mature at between 142 and 145 cm TL and females at about 156 cm TL (Castro 1996). According to Branstetter and McEachran (1986), in the western north Atlantic, males mature at 139 to 145 cm TL at four to five years, and females at 153 cm TL at six to seven years. However, these ages are unvalidated and based on a small sample. Branstetter and McEachran (1986) estimated the maximum age at ten years, and gave the von Bertalanffy parameters for combined sexes as: L = 171, K= 0.284, t_o= -1.5. The young are born at 55 to 60 cm TL in late May and early June in shallow coastal nurseries from Georgia to the Carolinas (Castro, 1996). Litters range from one to eight pups (Bigelow and Schroeder, 1948) with a mean of four. The gestation cycle lasts about a year; the reproductive cycle is biennial (Castro, 1996). According to Castro (1993b), the nurseries are on the seaward side of coastal islands of the Carolinas, at depths of two to four m. Carlson (pers. comm.) found neonates in depths up to 11 m. Castro (1993b) found neonates over muddy bottoms off Georgia and the Carolinas, while Hueter *et al.* found them over seagrass beds off west Florida (unpublished Mote Laboratory CSR data). Analysis of the Mote Laboratory CSR data reveals that neonates and juveniles were found off west Florida (from the Florida Keys to Tampa Bay) at temperatures of 18.5° to 33.6° C, salinities of 15.8 to 37.0 ppt, and DO of 3.5 to 9.0 ml/l. The neonates were found from April to September, while juveniles were found there nearly year-round.

Impact of fisheries: The blacktip shark is caught in many diverse fisheries throughout the world. Off the southeastern United States, it is caught in commercial longlines set in shallow coastal waters, but it is also pursued as a gamefish. There are localized drift gillnet fisheries in Federal waters off Florida, Georgia and South Carolina that target blacktips during their migrations, when the schools are close to shore in clear waters. Aircraft are often used to direct net boats to the migrating schools, often resulting in the trapping of very large schools. The species is considered vulnerable because it is pursued commercially throughout its range, has a low reproductive potential, and is often found in shallow coastal waters. Its habit of migrating in large schools along shorelines makes it extremely vulnerable to organized drift gillnet fisheries.

***Essential Fish Habitat for Blacktip Shark (Figure 6-15 a-e)*:**

- **Neonates/early juveniles (≤99 cm):** Shallow coastal waters to the 25 m isobath, from Bull's Bay, SC at 33.5° N, south to Cape Canaveral, FL at 28.5° N; also, on the west coast of Florida from Thousand Islands at 26° N to Cedar Key, FL at 29° N, especially Tampa Bay and Charlotte Harbor, FL. Additionally, as displayed on Figure 6-15e: shallow coastal waters with muddy bottoms less than five meters deep on the seaward side of coastal islands from Apalachee Bay to St. Andrews Bay, FL.

- **Late juveniles/subadults (100 to 155 cm):** Shallow coastal waters from the shoreline to the 25 m isobath: from Cape Hatteras, NC at 35.25° N to 29° N at Ponce de Leon Inlet; the west coast of Florida, including the Florida Keys and Florida Bay, north to Cedar Key at 29° N; from Cape San Blas, FL north of 29.5° N to the east coast of the Mississippi River delta north of 29° N; also, the west coast of Texas from Galveston, west of 94.5° N, to the U.S./Mexico border.

- **Adults (≥156 cm):** Shallow coastal waters of the Outer Banks, NC from the shoreline to the 200 m isobath between 36° N and 34.5° N; shallow coastal waters offshore to the 50 m isobath from St. Augustine, FL (30° N) to offshore Cape Canaveral, FL (28.5° N); on the west coast of Florida, shallow coastal waters to the 50 m isobath from 81° W in Florida Bay, to 85° W, east of Cape San Blas, FL.

Bull shark (*Carcharhinus leucas*). The bull shark is a large, shallow water shark that is cosmopolitan in warm seas and estuaries (Castro, 1983). It often enters fresh water, and may penetrate hundreds of kilometers upstream. Habitat associations are summarized in Table 6.3.16.

Reproductive potential: Males mature at 210 to 220 cm TL or 14 to 15 years of age, while females mature at >225 cm TL or 18+ years of age (Branstetter and Stiles, 1987). Growth parameters have been estimated by Branstetter and Stiles (1987) as L = 285 cm TL, K= 0.076, t_o = -3.0 yr. Thorson and Lacy (1982) estimated that females reached “their larger size” at approximately 16 years and that males of maximum size were 12 years old. The pups measure about 75 cm TL at birth (Clark and von Schmidt, 1965). Jensen (1976) stated that litters ranged from one to ten pups and that the average size was 5.5 pups. The gestation period is estimated at ten to eleven months (Clark and von Schmidt, 1965). The length of the reproductive cycle has not been published, but it is probably biennial. In the United States the nursery areas are in low-salinity estuaries of the Gulf of Mexico Coast (Castro, 1983) and the coastal lagoons of the east coast of Florida (Snelson *et al.* 1984). Hueter (CSR data), working off the Florida west coast, found neonates in Yankeetown, Tampa Bay, and Charlotte Harbor from May to August. The neonates were in temperatures of 28.2° to 32.2° C, with salinities of 18.5-28.5 ppt. Hueter (CSR data) found juveniles off the west coast of Florida in temperatures of 21.0° to 34.0° C, salinities of 3.0 to 28.3 ppt, and DO of 3.7 to 8.4 ml/l.

Impact of fisheries: The bull shark is a common coastal species that is fished in both artisanal and industrial/modern fisheries. Clark and von Schmidt (1965) found it to be the most common shark caught in their survey of the sharks of the central Gulf coast of Florida, accounting for 18 percent of the shark catch. Dodrill (1977) reported it to be the seventh most commonly taken shark at Melbourne Beach, Florida, composing 8.6 percent of all longline landings. Thorson (1976) recorded a marked decline of the Lake Nicaragua-Rio, San Juan population from 1963 to1974, resulting from a small-scale, but sustained commercial fishing operation. This fishery intensified in 1968, and by 1972 bull sharks in the area had become so scarce that Thorson (1976) predicted that any other developments would eliminate the bull shark from Lake Nicaragua. Russell (1993) indicated that the bull shark constituted three percent of the shark catch in the directed shark fishery in the U.S. Gulf of Mexico. Castillo (1992) referred to the species in Mexico as “intensely exploited in both coasts.” The bull shark is vulnerable to overfishing because of its slow growth, limited reproductive potential, and because it is pursued in numerous fisheries.

***Essential Fish Habitat for Bull Shark (Figure 6-16 a-d)*:**

- **Neonate/early juveniles (≤110 cm TL):** In shallow coastal waters, inlets and estuaries in waters less than 25 m deep: from just north of Cape Canaveral, FL at 29° N to just south of Cape Canaveral, FL at 28° N; from just south of Charlotte Harbor, FL at 26.5° N north to Cedar Key, FL at 29° N; the mouth of Mobile Bay, AL from 87.75° W to 88.25° W; the mouth of Galveston Bay, TX from 94.5° W to 95° W; from South Padre Island, TX south of 28.5° N to Laguna Madre, TX at 27° N.

- **Late juveniles/subadults (111 to 225 cm TL):** In shallow coastal waters, inlets and estuaries in waters less than 25 m deep: from Savannah Beach, GA at 32° N southward to the Dry Tortugas, FL; from Ten Thousand Islands, FL at 26° N north to northern Cedar Key, FL at 29° N; from Apalachiacola, FL at 85° W to the Mobile Bay, AL area at 88.5° W; from just east of Galveston Bay, TX at 94.5° W to the U.S./Mexico border.

- **Adults (≥226 cm TL):** In shallow coastal waters, inlets and estuaries in waters less than 25 m deep: from just south of Charlotte Harbor, FL at 26.5° N north to Anclote Key, FL at 28° N.

Caribbean reef shark *(Carcharhinus perezi)*. The Caribbean reef shark inhabits the southeast coast of Florida, the Caribbean, and the west Atlantic south to Brazil. This is a poorly known, bottom-dwelling species that inhabits shallow coastal waters, usually around coral reefs (Castro, 1983). Habitat associations are summarized in Table 6.3.17.

Reproductive potential: Males mature about 170 cm TL and females at about 200 cm TL. Pups are born at about 70 cm TL, litters consisting of four to six pups. The reproductive cycle is biennial (Castro, unpub.). The nurseries have not been described.

Impact of Fisheries: This FMP prohibits possession of Caribbean reef sharks as a precautionary measure.

***Essential Fish Habitat for Caribbean Reef Shark (Figure 6-17 a-c)*:**

- **Neonate/early juveniles (≤105 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults (106 to 199 cm TL):** Shallow coastal waters of the Florida Keys less than 25 m deep from Key Largo to the Dry Tortugas.

- **Adults (≥200 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

Dusky shark (*Carcharhinus obscurus*). The dusky shark is common in warm and temperate continental waters throughout the world. It is a migratory species which moves north-south with the seasons. This is one of the larger species found from inshore waters to the outer reaches of continental shelves. It is important as a commercial species as well as a game fish. Habitat associations are summarized in Table 6.3.18.

Reproductive potential: Males mature at 290 cm TL and reach at least 340 cm TL. The females mature at about 300 cm TL and reach up to 365 cm TL. The dusky shark matures at about 17 years and is considered a slow growing species (Natanson, 1990). Litters consist of six to14 pups, which measure 85 to 100 cm TL at birth (Castro, 1983). The gestation period is believed to be about 16 months (Clark and von Schmidt, 1965), but this has not been confirmed. Natanson (1990) gave the following parameters for males L_{max}= 351 cm FL (420 cm TL), K= .047, t_o =   5.83; and females at L_{max}= 316 cm TL (378 cm TL) K= .061, t_o=-4.83. The growth rate is believed to be about ten cm/yr for the young and fivr cm/yr for the adults. The nursery areas are in coastal waters. Castro (1993c) reported that dusky sharks gave birth in Bulls Bay, SC, in April and May. Musick and Colvocoresses (1986) stated that the species gives birth in the Chesapeake Bay, MD in June and July.

Impact of fisheries: The dusky shark has played an important role in the coastal shark fisheries for flesh and fins, and is commonly taken as bycatch in the swordfish and tuna fisheries. The dusky shark is one of the slowest growing requiem sharks and is often caught on both coastal and pelagic longlines, making it highly vulnerable to overfishing. This FMP prohibits possession of the dusky shark due to significant declines in catch rates in the last two decades, and because of its limited reproductive potential.

***Essential Fish Habitat for Dusky Shark (Figure 6-18 a-e)*:**

- **Neonate/early juveniles (≤115 cm TL):** Shallow coastal waters, inlets and estuaries to the 25 m isobath from the eastern end of Long Island, NY at 72° W south to Cape Lookout, NC at 34.5° N; from Cape Lookout south to West Palm Beach, FL (27.5° N), shallow coastal waters, inlets and estuaries and offshore areas to the 100 m isobath.

- **Late juveniles/subadults (116 to 300 cm TL):** Off the coast of southern New England from 70° W west and south, coastal and pelagic waters between the 25 and 200 m isobaths; shallow coastal waters, inlets and estuaries to the 200 m isobath from Assateague Island at the Virginia/Maryland border (38° N) to Jacksonville, FL at 30° N; shallow coastal waters, inlets and estuaries to the 500 m isobath continuing south to the Dry Tortugas, FL at 83° W.

- **Adults (≥301 cm TL):** Pelagic waters offshore the Virginia/North Carolina border at 36.5° N south to Ft. Lauderdale, FL at 28° N between the 25 and 200 m isobaths.

Galapagos shark (*Carcharhinus galapagensis*). The Galapagos shark is circumtropical in the open ocean and around oceanic islands (Castro, 1983). It is very similar to the dusky shark and is often mistaken for it, although the dusky prefers continental shores (Castro, 1983). The Galapagos shark is very seldom seen in the continental United States. A few Galapagos sharks are undoubtedly caught off the east coast every year, but they can be easily misidentified as dusky sharks (Castro, pers. comm.). Habitat associations are summarized in Table 6.3.19.

Reproductive potential: Males reach maturity between 205 and 239 cm TL and females between 215 and 245 cm TL (Wetherbee *et al.*, 1996). Pups are born at slightly over 80 cm TL and litters range from four to16 pups, the average being 8.7. The gestation cycle is estimated to last about a year (Wetherbee *et al.*, 1996), but the length of the reproductive cycle is not known.

Impact of Fisheries: This FMP prohibits possession of Galapagos sharks as a precautionary measure.

***Essential Fish Habitat for Galapagos Shark (reference Fig. 6-19 a)*:**

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults (≥215 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

Lemon shark (*Negaprion brevirostris*). The lemon shark is common in the American tropics, inhabiting shallow coastal areas, especially around coral reefs. It is reported to use coastal mangroves as some of its nursery habitats, although this is not well documented in the literature (S. Gruber, pers. comm.). The primary population in continental U.S. waters is found off south Florida, although adults stray north to the Carolinas and Virginia in the summer. Habitat associations are summarized in Table 6.3.20.

Reproductive potential: Lemon sharks mature at about 228 cm TL (Springer, 1950b). Brown and Gruber (1988) estimated an age at maturity of 11.6 years for males and 12.7 years for females, showing the species to be slow growing and long lived. Brown and Gruber reported the von Bertalanffy parameters as: L =317.65, K= .057, and t_o= -2.302. Litters consist of five to 17 pups, which measure about 64 cm TL at birth (Springer 1950b; Clark and von Schmidt 1965). Its reproductive cycle is biennial (Castro, 1993c) and gestation lasts ten (Springer, 1950b) to12 months (Clark and von Schmidt, 1965). Its nurseries are in shallow waters around mangrove islands (Springer 1950b) off tropical Florida and the Bahamas. Hueter (CSR data) found lemon shark neonates in Tampa Bay, FL during the month of May, at temperatures of 22.0° to 25.4° C, salinities of 26.8 to 32.6 ppt, and DO of 5.9 to 9.6 ml/l. He also found juveniles over a wider area off western Florida and in a wider range of temperatures and salinities.

Impact of fisheries: The lemon shark is caught throughout its range, although it is not a primary, commercially important species along the Atlantic coast. Anecdotal evidence indicates that lemon sharks are vulnerable to local depletions.

***Essential Fish Habitat for Lemon Shark (Figure 6-20 a-d)*:**

- **Neonate/early juveniles (≤90cm TL):** Shallow coastal waters, inlets and estuaries out to the 25 m isobath from Savannah, GA at 32° N, south to Indian River Inlet, FL at 29° N; shallow coastal waters, inlets and estuaries from Miami around peninsular Florida to Cape Sable at 25.25° N including the Keys in waters less than 25 m deep; waters of Tampa Bay, FL including waters immediately offshore the mouth of the bay; shallow coastal waters, inlets and estuaries from South Padre Island, TX at 95.5° N south to the U.S./Mexico border in waters less than 25 m deep.

- **Late juveniles/subadults (91 to 228 cm TL):** Shallow coastal waters, inlets and estuaries offshore to the 25 m isobath, west of 79.75° W from Bull's Bay, SC to south of Cape Canaveral (West Palm Beach), FL at 28° N; Shallow coastal waters, inlets and estuaries offshore to the 25 m isobath from Miami at 25.5° N, around peninsular Florida to Tampa Bay, FL (including the Keys) to 28° N; shallow coastal waters, inlets and estuaries offshore to the 25 m isobath off the south coast of Puerto Rico from 66° W to 67° W.

- **Adults (≥229 cm TL):** Shallow coastal waters, inlets and estuaries offshore to the 25 m isobath from Cumberland Island, GA at 31° N to St. Augustine, FL at 31° N; from West Palm Beach, FL at 27° N around peninsular Florida to 28.5° N near Anclote Key in shallow coastal waters, inlets and estuaries and offshore to the 25 m isobath.

Narrowtooth shark (*Carcharhinus brachyurus*). This is a coastal-pelagic species of widespread distribution in warm temperate waters throughout the world. In general, it is a temperate shark, absent or rare in tropical waters (Bass *et al.*, 1973). Although the species has been reported for the California coast by Kato *et al.* (1967) (as *C. remotus*), and for the southwest Atlantic (Chiaramonte. pers. comm.), few data exist for the western north Atlantic. Habitat associations are summarized in Table 6.3.21.

Reproductive potential: Males mature between 200 and 220 cm TL, and females mature below 247 cm TL. The young are born at about 60 to 70 cm TL. Six pregnant females averaged 16 embryos, with a range of 13 to 20 pups per litter (Bass *et al.*, 1973). Walter and Ebert (1991) calculated age at sexual maturity at 13 to 19 years for males and 19 to 20 years for females. Gestation is believed to last a year (Cliff and Dudley, 1992). The length of the reproductive cycle is not known, but it is probably biennial as it is for most large carcharhinid sharks.

Impact of fisheries: Because it appears to be a very slow growing carcharhinid (based on the unvalidated ages by Walter and Ebert (1991)), the narrowtooth shark is probably vulnerable to overfishing. This FMP prohibits possession of narrowtooth sharks as a precautionary measure.

***Essential Fish Habitat for Narrowtooth Shark (Figure 6-21 a)*:**

- **Neonate/early juveniles (≤100 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults (101 to 230 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults (≥231cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

Night shark (*Carcharhinus signatus*). This carcharhinid shark inhabits the waters of the western north Atlantic from Delaware to Brazil and the west coast of Africa. It is a tropical species that seldom strays northward. It is usually found at depths greater than 275 to 366 m during the day and about 183 m at night (Castro, 1983). Habitat associations are summarized in Table 6.3.22.

Reproductive potential: There is little information on night shark reproductive processes. Litters usually consist of 12 to 18 pups which measure 68 to 72 cm TL at birth (Castro, 1983). Length at maturity has been reported for females as 150 cm FL (178 cm TL) (Compagno, 1984). The nurseries remain undescribed.

Impact of fisheries: The night shark was abundant along the southeast coast of the United States and the northwest coast of Cuba before the development of the swordfish fishery of the 1970s. Martinez (1947) stated that the Cuban shark fishery relied heavily on the night shark, which constituted 60 to 75 percent of the total shark catch, and that the average annual catch for 1937 to1941 was 12,000 sharks. Guitart Manday (1975) documented a precipitous decline in night shark catches off the Cuban northwest coast during the years 1971 to 1973. Berkeley and Campos (1988) stated that this species represented 26.1 percent of all sharks caught in swordfish fisheries studied by them along the east coast of Florida from 1981 to 1983. Anecdotal evidence from commercial swordfish fishermen also indicates that in the late 1970s it was not unusual to have 50 to 80 dead night sharks, usually large gravid females, in every set from Florida to the Carolinas. During the 1970s sports fishermen in south Florida often resorted to catching night sharks when other more desirable species (marlins) were not biting. The photographic record of sport fishing trophies landed shows that large night sharks were caught daily and landed at the Miami docks in the 1970s. Today, the species is rare along the southeast coast of the United States. The decline of the night shark may be an example of how a species can decline due to bycatch mortality. This FMP prohibits possession of night sharks due to evidence of stock declines.

***Essential Fish Habitat for Night Shark (Figure 6-22 a-d)*:**

- **Neonate/early juveniles (≤100 cm TL):** At this time, the information available is insufficient to identify EFH for this life stage.

- **Late juveniles/subadults (101 to 178 cm TL):** From offshore Assateague Island, MD at 38° N south to offshore Cape Fear at 33.5° N, from the 100 to 2,000 m isobath

- **Adults (≥179 cm TL):** In the South Atlantic Bight, from the 100 m isobath to either the 2,000 m isobath, 100 miles from shore, or the EEZ boundary, whichever is nearest, from 36° N offshore Oregon Inlet, NC to 25.5° N, off the coast of Miami, FL.

<u>Sandbar shark (*Carcharhinus plumbeus*)</u>. The sandbar shark is cosmopolitan in subtropical and warm temperate waters. It is a common species found in many coastal habitats. It is a bottom-dwelling species most common in 20 to 55 m of water, but occasionally found at depths of about 200 m. Habitat associations are summarized in Table 6.3.23.

Reproductive potential: The sandbar shark is a slow growing species. Both sexes reach maturity at about 180 cm TL (Castro, 1983). Alternative lengths of maturity cited have been >136 cm PCL (Sminkey and Musick, 1995) and 150 cm FL (Casey and Natanson, 1992); all are roughly equivalent when converted using equations of Sminkey and Musick (1995) and Kohler *et al.* (1996). Estimates of age at maturity range from 15 to 16 years (Sminkey and Musick, 1995) to 29 to 30 years (Casey and Natanson, 1992), although 15 to 16 years is the commonly accepted age of maturity. The von Bertalanffy growth parameters were proposed for combined sexes are L = 186 cm FL (224 cm TL; 168 cm PCL), K= 0.046, t_o= -6.45 by Casey and Natanson (1992); and re-evaluated by Sminkey and Musick (1995) as L = 164 cm PCL (219 cm TL; 182 cm Fl), K= 0.089, t_o= -3.8. Young are born at about 60 cm TL (smaller in the northern parts of the North American range) from March to July. Litters consist of one to14 pups, with nine being the average (Springer 1960). The gestation period lasts about a year and reproduction is biennial (Musick *et al*,. 1993). Hoff (1990) used an age at maturity of 15 years, a life span of 35 years, and a two-year reproductive cycle, to calculate that each female may reproduce only ten times. New maturity estimates and the increased mortality in the fishery may reduce that reproductive potential much further. In the United States the sandbar shark has its nurseries in shallow coastal waters from Cape Canaveral, FL (Springer, 1960), to Great Bay, NJ (H.L. Pratt, Jr, pers. comm.). Delaware Bay and Chesapeake Bay, MD are important nurseries. Juveniles return to Delaware Bay after a winter absence around May 15, and are found as far north as Martha's Vineyard, MA in the summer. Neonates have been captured in Delaware Bay in late June. Young of the year were present in Delaware Bay until early October when the temperature fell below 21° C. Sandbar sharks were captured in varying salinities but no specimens were caught there at salinities below 22 ppt (H.L.Pratt, Jr, pers. comm., SEW, 1998). Another nursery may exist along the west coast of Florida and along the northeast Gulf of Mexico. Hueter (CSR data) found neonates off Yankeetown, FL, from April to July, in temperatures of 25.0° to 29.0° C, and salinities of 20.4 to 25.9 ppt. Neonate sandbar sharks were found in an area between Indian Pass and St. Andrew Sound in June when the temperature had reached 25° C (J. Carlson, NMFS, ms1998).

Impact of fisheries: The sandbar shark is one of the most important commercial species in the shark fishery of the southeastern United States, along with blacktip sharks. It is a preferred species because of the high quality of its flesh and large fins. Commercial longline fishermen pursue sandbar stocks in their north-south migrations along the coast; their catches can be as much as 80 to 90 percent sandbar sharks in some areas. Large numbers of juvenile sandbar sharks are caught in drift gillnets set in shallow waters along the southeastern coast of the United States. However, many of those gillnet fisheries have been, or are being, prohibited by state governments. Musick *et al.* (1993) have documented a severe decline in CPUE of the sandbar shark in the Chesapeake Bay area. It is considered highly vulnerable to overfishing because of its slow maturation and heavy fishing pressure, as evidenced in the catch per unit effort (CPUE) declines in U.S. fisheries.

***Essential Fish Habitat (EFH) for Sandbar Shark (Figure 6-23 a-e)*:**

- **Neonates/early juveniles (≤90 cm):** Shallow coastal areas to the 25 m isobath from Montauk, Long Island, NY at 72° W, south to Cape Canaveral, FL at 80.5° W(all year); nursery areas in shallow coastal waters from Great Bay, NJ to Cape Canaveral, FL, especially Delaware and Chesapeake Bays (seasonal-summer); also shallow coastal waters to up to a depth of 50 m on the west coast of Florida and the Florida Keys from Key Largo at 80.5° W north to south of Cape San Blas, FL at 85.25° W. Typical parameters: salinity-greater than 22 ppt; temperatures-greater than 21° C.

- **Late juveniles/subadults (91 to 179 cm):** Offshore southern New England and Long Island, all waters, coastal and pelagic, north of 40° N and west of 70° W; also, south of 40° N at Barnegat Inlet, NJ, to Cape Canaveral, FL (27.5° N), shallow coastal areas to the 25 m isobath; also, in the winter, from 39° N to 36° N, in the Mid-Atlantic Bight, at the shelf break, benthic areas between the 100 and 200 m isobaths; also, on the west coast of Florida, from shallow coastal waters to the 50 m isobath, from Florida Bay and the Keys at Key Largo north to Cape San Blas, FL at 85.5° W.

- **Adults (≥180 cm):** On the east coast of the United States, shallow coastal areas from the coast to the 50 m isobath from Nantucket, MA, south to Miami, FL; also, shallow coastal areas from the coast to the 100 m isobath around peninsular Florida to the Florida panhandle at 85.5° W, near Cape San Blas, FL including the Keys and saline portions of Florida Bay.

- **Habitat Areas of Particular Concern:** Important nursery and pupping grounds have been identified in shallow areas and the mouth of Great Bay, NJ, lower and middle Delaware Bay, lower Chesapeake Bay, MD and near the Outer Banks, NC, in areas of Pamlico Sound adjacent to Hatteras and Ocracoke Islands and offshore those islands.

Silky shark (*Carcharhinus falciformis*). The silky shark inhabits warm, tropical and subtropical waters throughout the world. Primarily, the silky is an offshore, epipelagic shark, but juveniles venture inshore during the summer. The silky shark is one of the most abundant large sharks in the world. Habitat associations are summarized in Table 6.3.24.

Reproductive potential: Data on the silky shark are variable. There is a strong possibility that different populations may vary in their reproductive potential. Litters range from six to 14 pups which measure 75 to 80 cm TL at birth (Castro, 1983). According to Bonfil *et al.* (1993), the silky shark in the Campeche Bank, Mexico, has a 12-month gestation period, giving birth to ten to 14 pups with an average of 76 cm TL during late spring and early summer, possibly every two years. Males mature at 225 cm TL (about ten years) and females at 232-245 cm TL (>12 yrs of age). The von Bertanffy parameters estimated by Bonfil *et al.* (1993) are: L = 311 cm TL, K= 0.101, t_o= -2.718 yr. Maximum ages were 20+ years for males and 22+ years for females (Bonfil *et al.* 1993). Springer (1967) describes reefs on the outer continental shelf as nursery areas. Bonfil *et al.*(1993) mentions the Campeche Bank as a prime nursery area in the Atlantic.

Impact of Fisheries: The silky shark is caught frequently in swordfish and tuna fisheries. Berkeley and Campos (1988) found it to constitute 27.2 percent of all sharks caught in swordfish vessels off the east coast of Florida from 1981 to1983. Bonfil *et al.* (1993) "consider the life-history characteristics of slow growth, late maturation, and limited offspring... point towards a very fragile resource. In all probability, local stocks of this species cannot support sustained heavy fishing pressure".

***Essential Fish Habitat for Silky Shark (Figure 6-24 a-c)*:**

- **Neonate/early juveniles (≤97 cm TL):** Waters off Cape Hatteras, NC between the 100 and 2,000 m isobaths; plus shallow coastal waters just north and immediately west of Cape Hatteras; waters off St. Augustine, FL south to off Miami in depths 25 to 1,000 m, (likely along the west edge of the Gulf Stream); off northwest FL- De Soto Canyon area between the 200 and 2,000 m isobaths.

- **Late juveniles/subadults (98 to 231 cm TL):** Waters off the mouth of the Chesapeake Bay, MD south to waters offshore west of the North Carolina/ South Carolina border from the 50 to 2,000 m isobath; from the North Carolina/ South Carolina border south to Key West paralleling the 200 m isobath; the area northwest of Key West to west of Ten Thousand Islands between the 50 and 2,000 m isobaths.

- **Adults (≥232 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

Spinner shark (*Carcharhinus brevipinna*). The spinner shark is a common, coastal-pelagic, warm-temperate and tropical shark of the continental and insular shelves (Compagno, 1984). It is often seen in schools, leaping out of the water while spinning. It is a migratory species, but its patterns are poorly known. Off eastern north America it ranges from Virginia to Florida and in the Gulf of Mexico. Habitat associations are summarized in Table 6.3.25.

Reproductive potential: Males mature at 130 cm TL or four to five years, females mature at 150 to 155 cm TL or seven to eight years (Branstetter, 1987). According to Branstetter (1987), males reach maximum size at ten to 15 years and females at 15 to

20 years. However, he added the caveat that “as sharks near their maximum size, growth is slower, therefore their maximum ages may be much greater”. Branstetter (1987) gave von Bertalanffy parameters for both sexes were: L = 214 cm, K= 0.212, t_o = -1.94 yr. The ages have not been validated. According to Garrick (1982), the species reaches 278 cm TL. The young are born at 60 to 75 cm TL in late May and early June. The litters usually consist of six to 12 pups (Castro 1983). It has a biennial reproductive cycle (Castro, 1993c). In the Carolinas the nursery areas are in shallow coastal waters (Castro, 1993c); However, the extent of the nursery areas is unknown. Hueter (CSR data) found juveniles along the west coast of Florida in temperatures of 21.9° to 30.1° C, salinities of 21.0 to 36.2 ppt, and DO 3.5 to 5.0 ml/l.

Impact of fisheries: Unknown. The spinner shark is similar in reproductive potential and habits to the blacktip shark, and its vulnerability to fisheries is probably very similar to that of the blacktip. In fact, the “blacktip-spinner complex” is a commonly used category that combines the landings of these two species because of species similarities and difficulties in distinguishing the two species.

***Essential Fish Habitat for Spinner Shark (Figure 6- 25 a-d)*:**

- **Neonate/early juveniles (≤90 cm TL):** Along the coast of the southeastern United States and the west coast of Florida, shallow coastal waters out to the 25 m isobath, from Cape Hatteras, NC at 35.25° N around Florida including Florida Bay and the Florida Keys, and north to 29.25° N. Additionally, as displayed in Figure 6-25e: shallow coastal waters with muddy bottoms less than five meters deep, on the seaward side of coastal islands, and in shallow bays along seagrass beds from Apalachee Bay to St. Andrews Bay, FL.

- **Late juveniles/subadults (91 to 154 cm TL):** Off the east coast from the Florida/Georgia border at 30.7° N south to 28.5° N, from shallow coastal waters to the 200 m isobath.

- **Adults (≥155 cm TL):** Off the east coast of Florida, from shallow coastal waters out to the 100 m isobath, from 30° N to 28.5° N offshore Cape Kennedy.

Tiger shark (*Galeocerdo cuvieri*). The tiger shark inhabits warm waters in both deep oceanic and shallow coastal regions (Castro, 1983). It is one of the larger species of sharks, reaching over 550 cm TL and over 900 kg. Its characteristic tiger-like markings and unique teeth make it one of the easiest sharks to identify. It is one of the most dangerous sharks and is believed to be responsible for many attacks on humans (Castro, 1983). Habitat associations are summarized in Table 6.3.26.

Reproductive potential: Tiger sharks mature at about 290 cm TL (Castro, 1983, Simpfendorfer 1992). The pups measure 68 to 85 cm TL at birth. Litters are large, usually consisting of 35 to 55 pups (Castro, 1983). According to Branstetter *et al.* (1987), males mature in seven years and females in ten years, and the oldest males and females were 15 and 16 years of age. The ages have not been validated. Branstetter *et al.* (1987) gave the growth parameters for an Atlantic sample as L = 440 cm TL, K= 0.107, t_o= -1.13 years, and for a Gulf of Mexico sample as L = 388 cm TL, K= 0.184, and t_o= -0.184. There is little data on the length of the reproductive cycle. Simpfendorfer (1992) stated that the females do not produce a litter each year. The length of the gestation period is also uncertain. Clark and von Schmidt (1965) stated that the gestation period may be “slightly over a year”. While this estimate has not been confirmed, it is probably correct, given that many large carcharhinid sharks have biennial reproduction and year-long gestation periods. The nurseries for the tiger shark appear to be in offshore areas, but they have not been described.

Impact of Fisheries: This species is frequently caught in coastal shark fisheries but is usually discarded due to low fin and meat value.

***Essential Fish Habitat for Tiger Shark (Figure 6-26 a-d)*:**

- **Neonate/early juveniles (≤120cm TL):** From shallow coastal areas to the 200 m isobath from Cape Canaveral, FL north to offshore Montauk, Long Island, NY (south of Rhode Island); and from offshore southwest of Cedar Key, FL north to the Florida/Alabama border from shallow coastal areas to the 50 m isobath.

- **Late juveniles/subadults (121 to 289cm TL):** Shallow coastal areas from Mississippi Sound (just west of Mississippi/Alabama border) to the 100 m isobath south to the Florida Keys; around the peninsula of Florida to the 100 m isobath to the Florida/Georgia border; north to Cape Lookout, NC from the 25 to100 m isobath; from Cape Lookout north to just south of the Chesapeake Bay, MD from inshore to the 100 m isobath; north of the mouth of Chesapeake Bay to offshore Montauk, Long Island, NY (to south of Rhode Island between the 25 and 100 m isobaths; south and southwest coasts of Puerto Rico from inshore to the 2,000 m isobath.

- **Adults (≥290 cm TL):** Offshore from Chesapeake Bay, MD south to Ft. Lauderdale, FL to the western edge of the Gulf Stream; from Cape San Blas, FL to Mississippi Sound between the 25 and 200 m isobaths; off the south and southwest coasts of Puerto Rico from inshore to the 2,000 m isobath.

6.3.3.6 Sand Tiger Sharks

Bigeye sand tiger (*Odontaspis noronhai*). This is one of the rarest large sharks. Its large eyes and uniform dark coloration indicate that it is a deep-water species. The few catch records that exist indicate that it frequents the upper layers of the water column at night. The species was originally described based on a specimen from Madeira. A few specimens were caught at depths of 600-1,000 m off Brazil (Compagno, 1984). A 321 cm TL immature female was caught in the Gulf of Mexico, about 70 miles east of Port Isabel, TX in 1984. Another specimen was caught in the tropical Atlantic

(5° N; 35° W) at a depth of about 100 m where the water was about 3,600 m deep (J. Castro, pers. comm.). These appear to be all the records for the species. Nothing is known of its habits. Possession of this species is prohibited in Atlantic waters of the United States. Habitat associations are summarized in Table 6.3.27.

***Essential Fish Habitat for Bigeye Sand Tiger Shark (Figure 6-27 a)*:**

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

Sand tiger shark (*Carcharias taurus*). The sand tiger is a large, coastal species found in tropical and warm temperate waters throughout the world. It is often found in very shallow water (<4 m) (Castro, 1983). It is the most popular large shark in aquaria, because, unlike most sharks, it survives easily in captivity. It has been fished for its flesh and fins in coastal longline fisheries; although possession of this species in Atlantic waters of the United States is now prohibited. Habitat associations are summarized in Table 6.3.28.

Reproductive potential: According to Gilmore (1983), males mature at about 191.5 cm TL. According to Branstetter and Musick (1994), males reach maturity at 190 to 195 cm TL or four to five years, and females at more than 220 cm TL or six years. The largest immature female seen by J. Castro (pers. comm.) was 225 cm TL and the smallest gravid female was 229 cm TL, suggesting that maturity is reached at 225 to 229 cm TL. The oldest fish in Branstetter and Musick's (1994) sample of 55 sharks was 10.5 years old, an age that has been exceeded in captivity (Govender *et al.*, 1991). The von Bertalanffy parameters, according to Branstetter and Musick (1994), are for males: L_{max}= 301 cm, K= 0.17, t_o= -2.25; and for females: L_{max}= 323 cm, K= 0.14, t_o= -2.56 yrs. Gilmore (1983) gave growth rates of 19 to 24 cm/yr for the first years of life of two juveniles born in captivity. The sand tiger has an extremely limited reproductive potential, producing only two young per litter (Springer, 1948). In North America, the sand tiger gives birth in March and April to two young that measure about 100 cm TL. Parturition (birth of the young) is believed to occur in winter in the southern portions of its range, and the neonates migrate northward to summer nurseries. The nursery areas are the following Mid-Atlantic Bight estuaries: Chesapeake, Delaware, Sandy Hook, and Narragansett Bays, as well as coastal sounds (R. Grant Gilmore, Harbor Branch Foundation; and J. A. Musick, VIMS, pers. comm.). Branstetter and Musick (1994) suggested that the reproductive cycle is biennial, but other evidence suggests annual parturition (R. G. Gilmore, pers. comm.).

Impact of fisheries: The species is extremely vulnerable to overfishing, because it congregates in coastal areas in large numbers during the mating season. These aggregations are attractive to fishermen, although the effects of fishing these aggregations probably contributes to local declines in the population abundance. Its limited fecundity (two pups per litter), probably contributes to its vulnerability. In the United States there was a very severe population decline in the early 1990s, with sand tigers nearly disappearing from North Carolina and Florida waters (R. Grant Gilmore, pers. comm.). Musick *et al.* (1993) documented a decrease in the Chesapeake Bight region of the U.S. Mid-Atlantic coast. In 1997, NMFS prohibited possession of this species in U.S. Atlantic waters.

***Essential Fish Habitat for Sand Tiger Shark (Figure 6-28 a-c)*:**

- **Neonate/early juveniles (≤125 cm TL):** Shallow coastal waters from Barnegat Inlet, NJ south to Cape Canaveral, FL to the 25 m isobath.

- **Late juveniles/subadults (126 to 220 cm TL):** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults (≥221 cm TL):** Shallow coastal waters to the 25 m isobath from Barnegat Inlet, NJ to Cape Lookout; from St. Augustine to Cape Canaveral, FL.

6.3.3.7 Whale Sharks (whale sharks may also be classified into the family of carpet sharks along with the nurse shark)

<u>Whale shark (*Rhincodon typus*)</u>. The whale shark is a sluggish, pelagic filter feeder, often seen swimming on the surface. It is the largest fish in the oceans, reaching lengths of 1210 cm TL and perhaps longer. It is found throughout all tropical seas, usually far offshore (Castro, 1983). Habitat associations are summarized in Table 6.3.29.

Reproductive potential: For many years the whale shark was believed to be oviparous, based on a presumably aborted egg case trawled from the Gulf of Mexico many years ago. Recent discoveries (Joung *et al.*, 1996) proved the whale shark to be viviparous and the most prolific of all sharks. The only gravid female examined carried 300 young in several stages of development. The embryos measured 580 to 640 mm TL, the largest appearing ready for birth. The length of the reproductive cycle is unknown, but is probably biennial such as the closely related nurse shark (*Ginglymostoma cirratum*) and most other large sharks (Castro, 1996). Based on unpublished information on the growth rate of one surviving embryo from a female reported by Joung *et al.* (1996), the whale shark may be the fastest growing shark. Only a handful of small juveniles has ever been caught, probably because of the extremely fast growth rate. The location of the whale shark nurseries is unknown and remains as one of the interesting mysteries of shark biology.

Impact of fisheries: There are very few observations of aggregations of whale sharks. The range of the whale shark may be extremely vast, perhaps encompassing entire ocean basins. Thus it may be necessary to consider whale shark fisheries on an ocean-wide perspective. There have been a few small fisheries for whale sharks in India, the Philippines, and Taiwan, but it is of little commercial importance elsewhere. The whale shark used to be fished for its flesh, but presently the fins and oil are also used. Generally, the size of the whale shark safeguards it from most fisheries. Records of the Taiwanese fishery demonstrate that whale sharks, like most elasmobranchs, are susceptible to overfishing. In 1997, NMFS prohibited possession of this species in U.S. Atlantic waters.

***Essential Fish Habitat for Whale Shark (Figure 6-29 a)*:**

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.4 Small Coastal Sharks (U.S. Fishery Status: Fully Fished)

6.3.4.1 Angel Sharks

Atlantic angel shark *(Squatina dumerili)*. The angel shark is a flattened shark that resembles a ray. It inhabits coastal waters of the United States from Massachusetts to the Florida Keys, the Gulf of Mexico, and the Caribbean. It is common from southern New England to the Maryland coast (Castro, 1983). Habitat associations are summarized in Table 6.3.30.

Reproductive potential: Maturity is probably reached at a length of 90 to 105 cm TL. The pups measure 28 to 30 cm TL at birth. Up to 16 pups in one litter have been observed (Castro 1983). Very little is known about its biology.

Impact of fisheries: This FMP prohibits possession of this species as a precautionary measure.

***Essential Fish Habitat for Atlantic Angel Shark (Figure 6-30 a-e)*:**

- **Neonate/early juveniles (≤ 50 cm TL):** Off the coast of southern New Jersey, Delaware, and Maryland from 39° N to 38° N, in shallow coastal waters out to the 25 m isobath, including the mouth of Delaware Bay.

- **Late juveniles/subadults (51 to 105 cm TL):** (Identical to neonate EFH): Off the coast of southern New Jersey, Delaware, and Maryland from 39° N to 38° N, in shallow coastal waters out to 25 m isobath, including the mouth of Delaware Bay.

- **Adults (≥106 cm TL):** (Identical to neonate EFH): Off the coast of southern New Jersey, Delaware, and Maryland from 39° N to 38° N, in shallow coastal waters out to the 25 m isobath, including the mouth of Delaware Bay.

6.3.4.2 Hammerhead Sharks

Bonnethead (*Sphyrna tiburo*). The bonnethead is a small hammerhead that inhabits shallow coastal waters where it frequents sandy or muddy bottoms. It is confined to the warm waters of the western hemisphere (Castro, 1983). Habitat associations are summarized in Table 6.3.31.

Reproductive potential: Males mature at about 70 cm TL, and females at about 85 cm TL (Parsons, 1993). Litters consist of eight to12 pups, with the young measuring 27 to 35 cm TL at birth (Castro, 1983; Parsons, 1993). Parsons (1993) estimated the gestation period of two Florida populations at 4.5 to 5 months, one of the shortest gestation periods known for sharks. The reproductive cycle is annual (Castro, pers. obs.). Hueter (CSR data) found “young of the year” and juveniles in the west coast of Florida, at temperatures of 16.1° to 31.5° C , salinities of 16.5 to 36.1 ppt, and DO of 2.9 to 9.4 ml/l.

Impact of fisheries: The bonnethead is at a lesser risk of overfishing because it is a fast growing species that reproduces annually and, due to its small size, is generally not targeted by commercial fisheries. Although bonnetheads are caught as bycatch in gillnet fisheries operating in shallow waters of the southeastern United States, many of these fisheries have been prohibited by various states and therefore forced into deeper Federal waters where gillnets are less effective. Bonnethead bycatch in the U.S. Gulf of Mexico shrimp fishery seems to have remained stable over the last twenty years, from 1974 to 1994 (Pellegrin, 1996).

***Essential Fish Habitat for Bonnethead Shark (Figure 6-31 a-d)*:**

- **Neonate/early juveniles (≤50 cm TL):** Shallow coastal waters, inlets and estuaries less than 25 m deep from Jekyll Island, GA to just north of Cape Canaveral, FL; in shallow waters on the Gulf-side of the Florida Keys as far north as Cape Sable in water less than 25 m deep. Additionally, as displayed on Figure 6-31e: shallow coastal bays and estuaries less than five meters deep, from Apalachee Bay to St. Andrews Bay, FL.

- **Late juveniles/subadults (51 to 84 cm TL):** Shallow coastal waters, inlets and estuaries from Cape Fear, NC southward to West Palm Beach, FL in waters less than 25 m deep; shallow coastal waters, inlets and estuaries from Miami around peninsular Florida as far north as Cedar Key in waters less than 25 m deep; shallow coastal waters, inlets and estuaries from the Mississippi River westward to the Rio Grande River (Texas/Mexico border).

- **Adults (≥85 cm TL):** Shallow coastal waters, inlets and estuaries from Cape Fear, NC to Cape Canaveral, FL; shallow waters around the Florida Keys; shallow coastal waters from Mobile Bay, AL west to South Padre Island, TX from inshore to the 25 m isobath.

6.3.4.3 Requiem Sharks

Atlantic sharpnose shark (*Rhizoprionodon terraenovae*). The Atlantic sharpnose shark is a small coastal carcharhinid, inhabiting the waters of the northeast coast of North America. It is a common year-round resident along the coasts of South Carolina, Florida and in the Gulf of Mexico, and an abundant summer migrant off Virginia (Musick, pers. comm.). Frequently, these sharks are found in schools of uniform size and sex (Castro, 1983). Habitat associations are summarized in Table 6.3.32.

Reproductive potential: The male Atlantic sharpnose sharks mature at around 65 to 80 cm TL and grow to 103 cm TL. The females mature at 85 to 90 cm TL and reach a length of 110 cm TL. Litters range from four to seven pups, which measure 29 to 32 cm TL (Castro, 1983). Mating is in late June; the gestation period is about 11 to 12 months (Castro and Wourms, 1993). The von Bertalanffy growth parameter estimates for the species are L = 108, K= 0.359, t_o= -.985 yr (Branstetter, 1987). Cortés (1995) calculated the population's intrinsic rate of increase was, at best, r= .044, or a finite increase of $e_r = 1.045$. Off South Carolina the young are born in late May and early June in shallow coastal waters (Castro and Wourms 1993). Hueter (CSR data) found neonates off the west coast of Florida at Yankeetown and Anclote Key during the months of May to July. These neonates were found in temperatures of 24.0° to 30.7° C, salinities of 22.8 to 337 ppt, and DO of 5.7 ml/l. Larger juveniles were also found in the area in temperatures of 17.2° to 33.3° C, salinities of 22.8 to 35.5 ppt, and DO of 4.5 to 8.6 ml/l.

Impact of fisheries: Large numbers of sharpnose are taken as bycatch in the U.S. shrimp trawling industry. The Texas Recreational Survey, NMFS Headboat Survey, and the U.S. Marine Recreational Fishing Statistics Survey have estimated a slow increase in the sharpnose fishery. The Atlantic sharpnose is a fast-growing species that reproduces yearly. In spite of being targeted by recreational fisheries and the large bycatch in the shrimp industry, the populations seem to be maintaining themselves.

***Essential Fish Habitat for Atlantic Sharpnose (Figure 6-32 a-d)*:**

- **Neonate/early juveniles (≤55 cm TL):** Shallow coastal areas including bays and estuaries out to the 25 m isobath from Galveston Island south to the Rio Grande (Texas/Mexico border); from Daytona Beach north to Cape Hatteras, NC. Additionally, as displayed on Fig. 32e: shallow coastal bays and estuaries less than five meters deep, from Apalachee Bay to St. Andrews Bay, FL.

- **Late juveniles/subadults (56 to 84 cm TL):** Shallow coastal areas including bays and estuaries out to the 25 m isobath from Galveston Island south to the Rio Grande (Texas/Mexico border); off Louisiana from the Atchafalya River to Mississippi River Delta out to the 40 m isobath; from Daytona Beach, FL north to Cumberland Island, GA; Hilton Head Island, SC north to Cape Hatteras, NC out to the 25 m isobath (slightly deeper - to the 50 m isobath off North Carolina).

- **Adults (≥85 cm TL):** From Cape May, NJ south to the North Carolina/ South Carolina border; shallow coastal areas north of Cape Hatteras, NC to the 25 m isobath; south of Cape Hatteras between the 25 and 100 m isobaths; offshore St. Augustine, FL to Cape Canaveral, FL from inshore to the100 m isobath, Mississippi Sound from Perdido Key to the Mississippi River Delta to the 50 m isobath; coastal waters from Galveston to Laguna Madre, TX to the 50 m isobath.

Blacknose shark (*Carcharhinus acronotus*). The blacknose shark is a common coastal species that inhabits the western north Atlantic from North Carolina to southeast Brazil (Bigelow and Schroeder 1948). It is very abundant in coastal waters from the Carolinas to Florida and the Gulf of Mexico during summer and fall (Castro, 1983). Schwartz (1984) hypothesized that there are two separate populations in the west Atlantic. Habitat associations are summarized in Table 6.3.33.

Reproductive potential: Maturity is reached at about 100 cm TL. Litters consist of three to six pups, which measure 50 cm TL at birth (Castro, 1983). Dodrill (1977) estimated the gestation period to be ten to eleven months and suggested that the breeding cycle was biennial. Schwartz (1984) estimated that the largest adult male captured was 164 cm TL and was 9.6 years old, while an adult female 154 cm TL was also 9.6 years old. Castro (1983) stated that in South Carolina nursery areas were in shallow waters. The species is common throughout the year off Florida, suggesting that part of the population may be non-migratory and that nursery areas may exist in Florida, as well. Hueter (CSR data) found 13 neonates in the Ten Thousand Islands and off Sarasota in June and July at temperatures 29° to 30.1° C, salinities of 32.2 to 37.0 ppt, and DO of 6.5 ml/l. He also found "young of the year" and juveniles at temperatures of 17.3° to 34° C , salinities of 25.0 to 37.0 ppt, and DO of 4.8 to 8.5 ml/l.

Impact of fisheries: Large numbers of blacknose sharks are caught in shallow coastal waters of the southeastern United States. The species is vulnerable to overfishing because it has typical carcharhinid characteristics such as biennial reproductive cycle, and it is targeted in the shark fisheries in the southeastern United States.

***Essential Fish Habitat for Blacknose Shark (Figure 6-33 a-d)*:**

- **Neonate/early juveniles (≤75 cm TL):** Shallow coastal waters to the 25 m isobath from North Carolina/South Carolina border south to Cape Canaveral, FL; shallow waters to the 25 m isobath from Ten Thousand Islands north to just south of Tampa Bay, FL.

- **Late juveniles/subadults (76 to 99 cm TL):** Shallow coastal waters to the 25 m isobath from the Georgia/Florida border south to West Palm Beach, FL; shallow waters to the 25 m isobath from the Florida Keys north to the mouth of Tampa Bay, FL. Additionally, as displayed on Figure 6-33e: shallow coastal bays and estuaries less than five meters deep with expanses of seagrasses, from Apalachee Bay to St. Andrews Bay, FL

- **Adults (≥100 cm TL):** Shallow coastal waters to the 25 m isobath from St. Augustine south to Cape Canaveral, FL; shallow waters to the 25 m isobath from the Florida Keys north to Cedar Key, FL; Mississippi Sound from Mobile Bay, AL to the waters off Terrebonne Parish, LA in waters 25 to100 m deep.

<u>Caribbean sharpnose shark (*Rhizoprionodon porosus*)</u>. The Atlantic sharpnose and the Caribbean sharpnose sharks are cognate species, separable only by having different numbers of precaudal vertebrae (Springer, 1964). However, they have non-overlapping ranges - the Caribbean sharpnose shark inhabits the Atlantic from 24° N to 35° S, while the Atlantic sharpnose is found at latitudes higher than 24° N. Their biology is very similar. Habitat associations are summarized in Table 6.3.34.

Impact of Fisheries: This FMP prohibits possession of this species as a precautionary measure.

***Essential Fish Habitat for Caribbean Sharpnose (Figure 6-34 a)*:**

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

Finetooth shark (*Carcharhinus isodon*). This is a common inshore species of the west Atlantic. It ranges from North Carolina to Brazil. It is abundant along the southeastern United States and the Gulf of Mexico (Castro, 1983). Habitat associations are summarized in Table 6.3.35.

Reproductive potential: Males mature at about 130 cm TL and females mature at about 135 cm TL. The young measure 48 to 58 cm TL at birth. Litters range from two to six embryos, with an average of four. The gestation period lasts about a year, and the reproductive cycle is biennial. Some of the nurseries are in shallow coastal waters of South Carolina (Castro, 1993b).

Impact of fisheries: Large numbers of finetooth sharks are caught in drift gillnet fisheries off South Carolina, but most are not recorded by species (Castro, pers. obs). The finetooth shark is caught in large numbers along the southeastern United States, including, very recently, in the shallow nursery areas of South Carolina. It is vulnerable to overfishing because of its biennial reproductive cycle and small brood size.

***Essential Fish Habitat for Finetooth Shark (Figure 6-35 a-e)*:**

- **Neonate/early juveniles (≤90 cm TL):** Shallow coastal waters of South Carolina, Georgia, and Florida out to the 25 m isobath from 33° N to 30° N. Additionally, as displayed on Figure 6-35e: shallow coastal waters less than five meters deep with muddy bottoms, and on the seaward side of coastal islands from Apalachee Bay to St. Andrews Bay, FL, especially around the mouth of the Apalachicola River.

- **Late juveniles/subadults (91 to 135 cm TL):** (Identical to neonate EFH): Shallow coastal waters of South Carolina, Georgia, and Florida out to the 25 m isobath from 33° N to 30° N. Additionally, as displayed on Figure 6-35e: shallow coastal waters less than five meters deep with muddy bottoms, and on the seaward side of coastal islands from Apalachee Bay to St. Andrews Bay, FL, especially around the mouth of the Apalachicola River.

- **Adults (≥136 cm TL):** (Identical to neonate EFH): Shallow coastal waters of South Carolina, Georgia, and Florida out to the 25 m isobath from 33°N to

30° N. Additionally, as displayed on Figure 6-35e: shallow coastal waters less than five meters deep with muddy bottoms, and on the seaward side of coastal islands from Apalachee Bay to St. Andrews Bay, FL, especially around the mouth of the Apalachicola River.

Smalltail shark *(Carcharhinus porosus)*. This is a small, tropical and subtropical shark that inhabits shallow coastal waters and estuaries in the west Atlantic, from the Gulf of Mexico to south Brazil, and the east Pacific from the Gulf of California to Peru (Castro, 1983). A few specimens have been caught in the Gulf of Mexico off Louisiana and Texas (S. Branstetter, pers. comm.). Habitat associations are summarized in Table 6.3.36.

Reproductive potential: There is almost no published data on its reproductive processes. Females observed in Trinidad were in different stages of gestation, suggesting a wide breeding season. Embryos up to 35 cm TL were observed. The reproductive cycle appears to be annual.

Impact of fisheries: The species is marketed in many areas of Central America; Springer (1950a) stated that large numbers were sold in the Trinidad market. This FMP prohibits possession of this species as a precautionary measure.

***Essential Fish Habitat for Smalltail Shark (Figure 6-36 a)*:**

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.5 Pelagic Sharks (U.S. Fishery Status: Fully Fished)

6.3.5.1 Cow sharks

Bigeye sixgill shark (*Hexanchus vitulus*). This is a poorly known deep-water shark that was not described until 1969. Most specimens have been accidental captures at depths of 400 m in tropical waters (Castro, 1983). In North America most catches have come from the Bahamas and the Gulf of Mexico. Habitat associations are summarized in Table 6.3.37.

Impact of Fisheries: This FMP prohibits possession of this species as a precautionary measure.

***Essential Fish Habitat for Bigeye Sixgill Shark (Figure 6-37 a)*:**

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

Sevengill shark (*Heptranchias perlo*). This is a deep-water species of the continental slopes, where it appears to be most common at depths of 180 to 450 m. It has a world-wide distribution in deep tropical and warm temperate waters. In the United States the sevengill shark ranges from South Carolina to the Gulf of Mexico. Habitat associations are summarized in Table 6.3.38.

Reproductive potential: Maturity is reached at about 85-90 cm TL. Litters consist of nine to 20 pups, which measure about 25 cm TL at birth (Castro, 1983). According to Tanaka and Mizue (1977), off Kyushu, Japan the species reproduces year round. The lengths of the reproductive and gestation cycles are unknown. The location of the nurseries is unknown.

Impact of fisheries: The sharpnose sevengill shark is sometimes caught in large numbers as bycatch in fisheries using bottom trawls or longlines (Compagno, 1984). In North America it is occasionally seen in small numbers as bycatch of tilefish longlines (Castro, unpublished). This FMP prohibits possession of this species as a precautionary measure.

Essential Fish Habitat for Sevengill Shark (Figure 6-38 a):

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.
- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.
- **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

Sixgill shark (*Hexanchus griseus*). One of the largest sharks, the sixgill is a common, bottom-dwelling, species usually reported from depths of 180 to 1,100 m, in deep, tropical and temperate waters throughout the world (Castro, 1983). It often comes close to the surface at night, where it may take longlines set for other species. Juveniles stray into very shallow cool waters. Habitat associations are summarized in Table 6.3.39.

Reproductive potential: Very few mature sixgill sharks have been examined by biologists; thus the reproductive processes are poorly known. Ebert (1986) reported a 421-cm TL female to be gravid with term embryos. Harvey-Clark (1995) stated that males mature at 325 cm TL, without providing any evidence for this. The species has not been aged. It is probably long-lived, as the Greenland shark, another deep-water giant shark. The pups measure 60 to 70 cm TL at birth. Litters are large - up to 108 pups have been reported (Castro, 1983). Juveniles are often caught in coastal waters, suggesting that the nurseries are in waters much shallower than those inhabited by the adults. Nothing else is known about its nurseries.

Impact of fisheries: Although juveniles are common in deep continental shelf waters and often enter coastal waters, the adults are seldom taken (Springer and Waller, 1969; Ebert, 1986). Apparently, adults are in waters deeper than those regularly fished, or perhaps these very large animals break the gear and escape. Thus, the very deep habitat of the adults or perhaps their large size seem to convey some measure of protection from most fisheries. According to Harvey-Clark (1995), in 1991 the sixgill shark became the target of a directed, subsidized, longline fishery off British Columbia, Canada. At about the same time, the species also became of interest as an ecotourism resource, with several companies taking diving tourists out to watch sixgill sharks in their environment. The fishery was unregulated and lasted until 1993, when the commercial harvest of sixgill sharks was discontinued due to conservation and management concerns. According to Harvey-Clark (1995), diver observations of sharks decreased in 1993, and it was unclear at the time whether the fishery or the ecotourism could be sustained. It is difficult to evaluate the vulnerability of the sixgill shark because of the lack of fisheries or landings data. The only fishing operations on record collapsed in a few years, suggesting that the species may be very vulnerable to overfishing. This FMP prohibits possession of sixgill sharks as a precautionary measure.

***Essential Fish Habitat for Sixgill Shark (Figure 6-39 a)*:**

- **Neonate/early juveniles:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Late juveniles/subadults:** At this time, available information is insufficient for the identification of EFH for this life stage.

- **Adults:** At this time, available information is insufficient for the identification of EFH for this life stage.

6.3.5.2 Mackerel Sharks

Longfin mako shark (*Isurus paucus*). This is a deep dwelling lamnid shark found in warm waters. The species was not described until 1966 and it is very poorly known. Habitat associations are summarized in Table 6.3.40.

Reproductive potential: There is very little data on the reproductive processes of the longfin mako. Litters consist of two to eight pups, which may reach 120 cm TL at birth (Castro, unpublished).

Impact of fisheries: The longfin mako is a seasonal bycatch of the pelagic tuna and swordfish fisheries. Its flesh is of lesser quality than that of its congener, the shortfin mako. This FMP prohibits possession of this species as a precautionary measure.

***Essential Fish Habitat for Longfin Mako Shark (Figure 6-40 a-d)*:**

Note: At this time, insufficient data is available to differentiate EFH by size classes, therefore EFH is the same for all life stages.

- **Neonate/early juveniles:** Off the northeast U.S. coast from the 100 m isobath out to the EEZ boundary, from south Georges Bank to 35° N; from 35° N south to 28.25° N off Cape Canaveral, FL, from the 100 m isobath to the 500 m isobath; from 28.25° N south around peninsular Florida and west to 92.5° W in the Gulf of Mexico, from the 200 m isobath to the EEZ boundary.

- **Late juveniles/subadults:** (Identical to neonate EFH): Off the northeast U.S. coast from the 100 m isobath out to the EEZ boundary, from south Georges Bank to 35° N; from 35° N south to 28.25° N off Cape Canaveral, FL, from the 100 m isobath to the 500 m isobath; from 28.25° N south around peninsular Florida and west to 92.5° W in the Gulf of Mexico, from the 200 m isobath to the EEZ boundary.

- **Adults:** (Identical to neonate EFH): Off the northeast U.S. coast from the 100 m isobath out to the EEZ boundary, from south Georges Bank to 35° N; from 35° N south to 28.25° N off Cape Canaveral, FL, from the 100 m isobath to the 500 m isobath; from 28.25° N south around peninsular Florida and west to 92.5° W in the Gulf of Mexico, from the 200 m isobath to the EEZ boundary.

Porbeagle (*Lamna nasus*). The porbeagle is a lamnid shark common in deep, cold temperate waters of the north Atlantic, south Atlantic and south Pacific Oceans. It is highly esteemed for its flesh. There have been fisheries for this species in the north Atlantic for many years. Habitat associations are summarized in Table 6.3.41.

Reproductive potential: Very little is known about its reproductive processes. Aasen (1963) estimated that maturity was reached at 150 to 200 cm TL for males and 200 to 250 cm TL for females. Castro estimated that porbeagles reach 20 years of age and possibly 30. Shann (1911) reported an embryo 61 cm TL, and estimated that porbeagles were probably born at about 76 cm TL. Bigelow and Schroeder (1948) recorded a free swimming specimen at 76 cm TL. Gauld (1989) gave 3.7 as the mean number of embryos in a sample of 12 females. The frequency of reproduction is not known. According to Aasen (1963), the porbeagle probably reproduces annually, but there is no evidence to support this claim. The nurseries are probably in continental shelf waters.

Impact of fisheries: The porbeagle is presently targeted in northern Europe and along the northeast coast of North America. Whether the porbeagles in the north Atlantic constitute one or more separate stocks is not known. A small porbeagle fishery resumed in the early 1990s in the northeastern United States, after being practically non-existent for decades. Intensive fisheries have depleted the stocks of porbeagles in a few years wherever they have existed, demonstrating that the species can not withstand heavy fishing pressure. This FMP establishes a species-specific commercial quota for porbeagle sharks as a precautionary measure to ensure this species does not become overfished, pending an international assessment.

***Essential Fish Habitat (EFH) for Porbeagle Shark (Figure 6-41 a-d)*:**

- **Neonate/early juveniles (≤100 cm TL):** From the 100 m isobath to the EEZ boundary from offshore Cape May, NJ, approximately 39° N to approximately 42° N (west of Georges Bank).

- **Late juveniles/subadults (101 to 224 cm TL):** From the 200 m isobath to the EEZ boundary; from offshore Great Bay, approximately 38° N to approximately 42° N (west of Georges Bank).

- **Adults (≥225 cm TL):** From offshore Portland, ME south to Cape Cod, MA along the 100 m isobath out to the EEZ boundary, and from Cape Cod south to the 2,000 m isobath out to the EEZ boundary.

Shortfin mako shark (*Isurus oxyrinchus*). The shortfin mako is found in warm and warm-temperate waters throughout all oceans. It is an oceanic species at the top of the food chain, feeding on fast-moving fishes such as swordfish, tuna, and other sharks

(Castro, 1983). It is considered one of the great game fish of the world, and its flesh is considered among the best to eat. Habitat associations are summarized in Table 6.3.42.

Reproductive potential: According to Pratt and Casey (1983), females mature at about 7 years of age. Cailliet. *et al.* (1983) estimated the von Bertalanffy parameters (n= 44) for the shortfin as: L = 3210 mm, K= .072, t_o= -3.75. Cailliet and Mollet (1997) estimated that a female mako lives for approximately 25 years, matures at four to six years, has a two-year reproductive cycle, and a gestation period of approximately 12 months. The litters range from 12 to 20 pups, although only a handful have been examined (Castro, unpubl.). There is circumstantial evidence that the nursery areas are in deep tropical waters. The life span of the species has been estimated at 11.5 years (Pratt and Casey, 1983).

Impact of fisheries: The shortfin mako is a common bycatch in tuna and swordfish fisheries. Because of their high market value, shortfin mako are usually the only sharks retained in some pelagic fleets with high shark bycatch rates. Off the northeast coast of North America, most of the catch consists of immature fish (Casey and Kohler, 1992). The index of abundance for shortfin makos in the commercial longline fishery off the Atlantic coast of the United States shows a steady decline (Cramer, 1996a). The few indices available (Cramer, 1996a; Holts *et al.*,1996; ICES, 1995) indicate substantial population decreases. Because the species is commonly caught in widespread swordfish and tuna operations, it is reasonable to assume that similar decreases are occurring in areas for which there are limited data.

***Essential Fish Habitat (EFH) for Shortfin Mako (Figure 6-42 a-d)*:**

- **Neonate/early juveniles (≤95 cm TL):** Between the 50 and 2,000 m isobaths from Cape Lookout, NC, approximately 35° N, north to just southeast of Georges Bank (approximately 42° N and 66° W) to the EEZ boundary; and between the 25 and 50 m isobaths from offshore the Chesapeake Bay (James River) (North Carolina/Virginia border) to a line running west of Long Island, NY to just southwest of Georges Bank, approximately 67° W and 41° N.

- **Late juveniles/subadults (96 to 279 cm TL):** Between the 25 and 2,000 m isobaths from offshore Onslow Bay, NC north to Cape Cod, MA; and extending west between 38° N and 41.5° N to the EEZ boundary.

- **Adults (≥280 cm TL):** Between the 25 and 2,000 m isobaths from offshore Cape Lookout, NC north to Long Island, NY; and extending west between 38.5° N and 41° N to the EEZ boundary.

6.3.5.3 Requiem Sharks

Blue shark (*Prionace glauca*). One of the most common and widest-ranging of sharks, the blue shark is cosmopolitan in tropical, subtropical and temperate waters. It is a pelagic species that inhabits clear, deep, blue waters, usually in temperatures of 10° to 20° C, at depths greater than 180 m (Castro, 1983). Its migratory patterns are complex and encompass great distances, but are poorly understood. The biology, migrations, and the impact of fisheries on the blue shark must be considered on the basis of entire ocean basins. Males and females are known to segregate in many areas (Strasburg, 1958; Gubanov and Grigoryev, 1975). Strasburg (1958) showed that blue sharks are most abundant in the Pacific between latitudes of 40° N and 50° N. Habitat associations are summarized in Table 6.3.43.

Reproductive potential: Although some authors have examined very large numbers of blue sharks, the data on its size at maturity are imprecise. This may be due to poor criteria for maturity, incomplete samples, samples that did not include animals of all sizes, or some peculiarities of the blue shark. Pratt (1979) used different criteria for determining maturity of males and gave a range of 153 to 183 cm FL for male maturity, but when he used the standard criterion of clasper calcification, he observed that the males reached maturity at 183 cm FL (218 cm TL). Bigelow and Schroeder (1948) suggested that females mature at 213 to 243 cm TL. Strasburg (1958) stated that the smallest gravid female seen by him measured 214 cm TL. Nakano (1994) used data from 105,600 blue sharks and stated that females matured at 140 to160 cm (166 and 191 cm TL, using the regression of Pratt), and males at 130 to 160 cm PCL, based on clasper development.

This is probably the most prolific of the larger sharks; litters of 28 to 54 pups have been reported often (Bigelow and Schroeder, 1948; Pratt, 1979), but up to 135 pups in a litter have also been reported (Gubanov and Grigoryev, 1975). Nakano (1994) observed 669 pregnant females in the North Pacific and stated that the number of embryos ranged from one to 62, with an average of 25.6 embryos. Strasburg (1958) gave the birth size as 34 to 48 cm TL. Suda (1953) examined 115 gravid females from the Pacific Ocean and concluded that gestation lasts nine months and that birth occurs between December and April. Pratt (1979) examined 19 gravid females from the Atlantic and used data from 23 other Atlantic specimens to arrive at a gestation period of 12 months. Nakano (1994) stated that gestation lasts about a year, based on length frequency histograms, but did not state how many gravid animals had been observed nor showed any data. The length of the reproductive cycle is believed to be annual (W.L. Pratt, Jr, pers. comm.). Nakano (1994) gave the age at maturity as four or five years for males and five or six years for females, based on “growth equations”. According to Cailliet *et al.* (1983), blue sharks become reproductively mature at six or seven years of age and may reach 20 years. The nursery areas appear to be in open oceanic waters in the higher latitudes of the range. Strasburg (1958) attributed the higher CPUE in the 30° N to 40° N zone of the Pacific Ocean in summer to the presence of new born blue sharks, and commented on the absence of small blue sharks in the warmer parts of the range. Nakano (1994) also stated that parturition occurred in early summer between latitudes of 30° N to 40° N of the Pacific Ocean.

Impact of fisheries: Although finning is now prohibited in U.S. Atlantic waters, blue sharks have historically been finned and discarded because of the low value of their flesh. Large numbers of blue sharks are caught and discarded yearly in pelagic tuna and swordfish fisheries. The blue shark is one of the most abundant large vertebrates in the world, yet it my be vulnerable to overfishing because it is caught in tremendous numbers as bycatch in numerous longline fisheries. Preliminary catch rate information for some areas suggest that this species may be declining. This FMP establishes a species-specific quota for blue sharks as a precautionary measure to ensure the species does not become overfished, pending an international assessment.

***Essential Fish Habitat for Blue Shark (Figure 6-43 a-d)*:**

- **Neonate/early juveniles (≤75cm TL):** North of 40 N from Manasquan Inlet, NJ to Buzzards Bay, MA in waters from 25 m to the EEZ boundary.

- **Late juveniles/subadults (76 to 220 cm TL):** From 45 N (offshore Cape Hatteras, NC) in waters from the 25 m isobath to the EEZ boundary.

- **Adults (≥221 cm TL):** From 45 N (offshore Cape Hatteras, NC) in waters from the 25 m isobath to the EEZ boundary; extending around Cape Cod, MA to include the southern part of the Gulf of Maine.

Oceanic whitetip shark (*Carcharhinus longimanus*). The oceanic whitetip is one of the most common large sharks in warm oceanic waters (Castro, 1983). It is circumtropical and nearly ubiquitous in water deeper than 180 m and warmer than 21° C. Habitat associations are summarized in Table 6.3.44.

Reproductive potential: Both males and females appear to mature at about 190 cm TL (Bass *et al.*, 1973). The young are born at about 65-75 cm TL (Castro 1983). The number of pups per litter ranges from two to ten, with a mean of six (Backus *et al.*, 1956; Guitart Manday, 1975). The length of the gestation period has not been reported, but it is probably ten to 12 months as for most large carcharhinids. The reproductive cycle is believed to be biennial (Backus *et al.*, 1956). Although the location of nurseries has not been reported, preliminary work by Castro (pers. comm.) indicates that very young oceanic whitetip sharks are found well offshore along the southeastern United States in early summer, suggesting offshore nurseries over the continental shelves.

Impact of fisheries: Large numbers of oceanic whitetip sharks are caught as bycatch each year in pelagic tuna and swordfish fisheries. Strasburg (1958) reported that the oceanic whitetip shark constituted 28 percent of the total shark catch in exploratory tuna longline fishing south of 10° N in the central Pacific Ocean. According to Berkeley and Campos (1988), oceanic whitetip sharks constituted

2.1 percent of the shark bycatch in the swordfish fishery along the east coast of Florida in 1981 to1983. Guitart Manday (1975) demonstrated a marked decline in the oceanic whitetip shark landings in Cuba from 1971 to1973. The oceanic whitetip shark is probably vulnerable to overfishing because of its limited reproductive potential, and because it is caught in large numbers in various pelagic fisheries and in directed fisheries. There are no data on populations or stocks of the species in any ocean.

***Essential Fish Habitat for Oceanic Whitetip Shark (Figure 6-44 a-d)*:**

- **Neonate/early juveniles (≤115 cm TL):** In the vicinity of the Charleston Bump, from the 200 m isobath to the 2,000 m isobath, between 32.5° N and 31° N.

- **Late juveniles/subadults (116 to 190 cm TL):** Offshore the southeast U.S coast from 32° N to 26° N, from the 200 m isobath to the EEZ boundary, or 75° W, whichever is nearer.

- **Adults (≥191 cm TL):** Offshore the southeast U.S. coast from the 200 m isobath out to the EEZ boundary, from 36° N to 30° N; also, in the Caribbean, south of the U.S. Virgin Islands, from east of 65° W to the EEZ boundary or the 2,000 m isobath, whichever is nearer.

6.3.5.4 Thresher Sharks

Bigeye thresher shark (*Alopias superciliosus*). The bigeye thresher is cosmopolitan in warm and warm-temperate waters. It is a deep-water species which ascends to depths of 35 to 150 m at night. It feeds on squid and small schooling fishes (Castro, 1983), which it stuns with blows from its tail. This is one of the larger sharks, reaching up to 460 cm TL (Nakamura, 1935). Habitat associations are summarized in Table 6.3.45.

Reproductive potential: Males mature at about 270 cm TL and females at about 340 cm TL (Moreno and Moron, 1992). Litters consist of two pups, one in each uterus. Gestation probably lasts about a year, but there is no evidence to support this. The length of the reproductive cycle and the location of nursery areas are unknown.

Impact of fisheries: The bigeye thresher is often caught as bycatch of swordfish fisheries. A shark will often dislodge several baits before impaling or hooking itself. The flesh and fins of the bigeye thresher shark are of poor quality, thus it is usually discarded dead in swordfish and tuna fisheries. It is, however, marketed in some areas.

*Essential Fish Habitat for Bigeye Thresher Shark (Figure 6-45 a-c)***:**

- **Neonate/early juveniles (≤135 cm TL):** At this time, available information is insufficient to identify EFH for this life stage.

- **Late juveniles/subadults (136 to 339 cm TL):** Offshore North Carolina, from 36.5° N to 34° N, between the 200 and 2,000 m isobaths.

- **Adults (≥340 cm TL):** Offshore North Carolina, from 35.5° N to 35° N, between the 200 and 2,000 m isobaths.

Thresher shark (*Alopias vulpinus*). The common thresher shark is cosmopolitan in warm and temperate waters. It is found in both coastal and oceanic waters, but according to Strasburg (1958) it is more abundant near land. It is a large shark that uses its tremendously large tail to hit and stun the small schooling fishes upon which it feeds. Habitat associations are summarized in Table 6.3.46.

Reproductive potential: According to Strasburg (1958), females in the Pacific mature at about 315 cm TL. According to Cailliet and Bedford (1983), males mature at about 333 cm TL. Cailliet and Bedford (1983) stated that the age at maturity ranges from three to seven years. Litters consist of four to six pups, which measure 137 to 155 cm TL at birth (Castro, 1983). According to Bedford (1985), gestation lasts nine months and female threshers give birth annually every spring (March to June).

Impact of fisheries: Thresher sharks are caught in many fisheries. The most detailed data available are for the California drift gillnet fishery which started in 1977 for thresher sharks, shortfin makos, and swordfish, extending from the Mexican border to San Francisco, CA (Hanan, 1984). After 1982, the fishery expanded northward yearly, ultimately reaching the states of Oregon and Washington (Cailliet *et al.*, 1991). Thresher shark landings peaked in 1982, and the thresher shark resource quickly began to decline after that year (Bedford, 1987). Catches have continued to decline and the average size has remained small in spite of numerous regulations restricting fishing (Hanan *et al.*, 1993). Cailliet *et al.* (1991) summarized the condition of the resource by stating "The coastwise fishery for this once abundant shark is now a thing of the past." Legislation passed in 1986 limited the directed thresher shark fishery in the Pacific. Off the U.S. Atlantic coast, the CPUE has shown a considerable decline (Cramer, 1996).

*Essential Fish Habitat for Thresher Shark (Figure 6-46 a-d)***:**

- **Neonate/early juveniles (≤200 cm TL):** Offshore Long Island, NY and southern New England in the northeastern United States, in pelagic waters deeper than 50 m, between 70° W and 73.5° W, south to 40° N.

- **Late juveniles/subadults (200 to 319cm TL):** (Identical to neonate EFH): Offshore Long Island, NY and southern New England in the northeastern United States, in pelagic waters deeper than 50 m, between 70° W and 73.5° W, south to 40° N.

- **Adults (≥320 cm TL):** (Identical to neonate EFH): Offshore Long Island, NY and southern New England in the northeastern United States, in pelagic waters deeper than 50 m, between 70° W and 73.5° W, south to 40° N.

6.4 Summary Tables of Life History and Habitat Associations

TUNA

6.3-2. Atlantic Albacore (*Thunnus alalunga*)
6.3-3. Atlantic Bigeye Tuna (*Thunnus obesus*)
6.3-4. Atlantic Bluefin Tuna (*Thunnus thynnus*)
6.3-5. Atlantic Skipjack (*Katsuwonus pelamis*)
6.3-6. Atlantic Yellowfin Tuna (*Thunnus albacares*)

SWORDFISH

6.3-7. Swordfish (*Xiphias gladius*)

LARGE COASTAL SHARKS

Basking sharks - Cetorhnidae
6.3-8. basking shark , *Cetorhinus maximus*
Hammerhead sharks - Sphyrnidae
6.3-9. great hammerhead, *Sphyrna mokarran*
6.3-10. scalloped hammerhead, *S. lewini*
6.3-11. smooth hammerhead, *S. zygaena*
Mackerel sharks - Lamnidae
6.3-12. white shark, *Carcharodon carcharias*
Nurse sharks - Ginglymostomatidae
6.3-13. nurse shark, *Ginglymostoma cirratum*
Requiem sharks - Carcharhinidae
6.3-14. bignose shark, *Carcharhinus altimus*
6.3-15. blacktip shark, *C. limbatus*
6.3-16. bull shark, *C. leucas*
6.3-17. Caribbean reef shark, *C. perezi*
6.3-18. dusky shark, *C. obscurus*
6.3-19. Galapagos shark, *C. galapagensis*
6.3-20. lemon shark, *Negaprion brevirostris*
6.3-21. narrowtooth shark, *Carcharhinus brachyurus*
6.3-22. night shark, *C. signatus*
6.3-23. sandbar shark, *C. plumbeus*
6.3-24. silky shark, *C. falciformis*
6.3-25. spinner shark, *C. brevipinna*
6.3-26. tiger shark, *Galeocerdo cuvieri*
Sand tiger sharks - Odontaspididae
6.3-27. bigeye sand tiger, *Odontaspis noronhai*
6.3-28. sand tiger shark, *Odontaspis taurus*
Whale sharks - Rhinocodontidae
6.3-29. whale shark, *Rhinocodon typus*

SMALL COASTAL SPECIES

Angel sharks - Squatinidae
6.3-30. Atlantic angel sharks, *Squatina dumerili*
Hammerhead sharks - Sphyrnidae
6.3-31. bonnethead, *Sphyrna tiburo*
Requiem sharks - Carcharhinidae
6.3-32. Atlantic sharpnose, *Rhizoprionodon terraenovae*
6.3-33. blacknose shark, *Carcharhinus acronotus*
6.3-34. Caribbean sharpnose, *Rhizoprionodon porosus*
6.3-35. finetooth shark, *Carcharhinus isodon*
6.3-36. smalltail shark, *Carcharhinus porosus*

PELAGIC SHARKS

Cow sharks - Hexanchidae
6.3-37. bigeye sixgill shark, *Hexanchus vitulus*
6.3-38. sevengill shark, *Heptranchias perlo*
6.3-39. sixgill shark, *Hexanchus griseus*
Mackerel sharks - Lamnidae
6.3-40. longfin mako, *Isurus paucus*
6.3-41. porbeagle shark, *Lamna nasus*
6.3-42. shortfin mako, *Isurus oxyrinchus*
Requiem sharks - Carcharhinidae
6.3-43. blue shark, *Prionace glauca*
6.3-44. oceanic whitetip shark, *Carcharhinus longimanus*
Thresher sharks - Alopiidae
6.3-45. bigeye thresher, *Alopias superciliosus*
6.3-46. thresher shark, *A. vulpinus*

6.5 Essential Fish Habitat Maps (by species and life stage)

BASE MAPS
6-1. Geography Hydrography and Bathymetry

Tuna
6-2. Atlantic Albacore (*Thunnus alalunga*)
6-3. Atlantic Bigeye Tuna (*Thunnus obesus*)
6-4. Atlantic Bluefin Tuna (*Thunnus thynnus*)
6-5. Atlantic Skipjack (*Katsuwonus pelamis*)
6-6. Atlantic Yellowfin Tuna (*Thunnus albacares*)

SWORDFISH
6-7. Swordfish (*Xiphias gladius*)

LARGE COASTAL SHARKS
Basking sharks - Cetorhnidae
6-8. basking shark , *Cetorhinus maximus*
Hammerhead sharks - Sphyrnidae
6-9. great hammerhead, *Sphyrna mokarran*
6-10. scalloped hammerhead, *S. lewini*
6-11. smooth hammerhead, *S. zygaena*
Mackerel sharks - Lamnidae
6-12. white shark, *Carcharodon carcharias*
Nurse sharks - Ginglymostomatidae
6-13. nurse shark, *Ginglymostoma cirratum*
Requiem sharks - Carcharhinidae
6-14. bignose shark, *Carcharhinus altimus*
6-15. blacktip shark, *C. limbatus*
6-16. bull shark, *C. leucas*
6-17. Caribbean reef shark, *C. perezi*
6-18. dusky shark, *C. obscurus*
6-19. Galapagos shark, *C. galapagensis*
6-20. lemon shark, *Negaprion brevirostris*
6-21. narrowtooth shark, *Carcharhinus brachyurus*
6-22. night shark, *C. signatus*
6-23. sandbar shark, *C. plumbeus*
6-24. silky shark, *C. falciformis*
6-25. spinner shark, *C. brevipinna*
6-26. tiger shark, *Galeocerdo cuvieri*

Sand tiger sharks - Odontaspididae
6-27. bigeye sand tiger, *Odontaspis noronhai*
6-28. sand tiger shark, *Odontaspis taurus*
Whale sharks - Rhinocodontidae
6-29. whale shark, *Rhinocodon typus*

SMALL COASTAL SPECIES
Angel sharks - Squatinidae
6-30. Atlantic angel sharks, *Squatina dumerili*
Hammerhead sharks - Sphyrnidae
6-31. bonnethead, *Sphyrna tiburo*
Requiem sharks - Carcharhinidae
6-32. Atlantic sharpnose, *Rhizoprionodon terraenovae*
6-33. blacknose shark, *Carcharhinus acronotus*
6-34. Caribbean sharpnose, *Rhizoprionodon porosus*
6-35. finetooth shark, *Carcharhinus isodon*
6-36. smalltail shark, *Carcharhinus porosus*

PELAGIC SHARKS
Cow sharks - Hexanchidae
6-37. bigeye sixgill shark, *Hexanchus vitulus*
6-38. sevengill shark, *Heptranchias perlo*
6-39. sixgill shark, *Hexanchus griseus*
Mackerel sharks - Lamnidae
6-40. longfin mako, *Isurus paucus*
6-41. porbeagle shark, *Lamna nasus*
6-42. shortfin mako, *Isurus oxyrinchus*
Requiem sharks - Carcharhinidae
6-43. blue shark, *Prionace glauca*
6-44. oceanic whitetip shark, *Carcharhinus longimanus*
Thresher sharks - Alopiidae
6-45. bigeye thresher, *Alopias superciliosus*
6-46. thresher shark, *A. vulpinus*

6.6 Threats to Essential Fish Habitat

This section identifies the principal fishing and non-fishing related threats to shark, tuna, and swordfish EFH, as identified and described in Section 6.3 of this FMP. It also provides examples and information concerning the relationship between those threats and EFH, and describes conservation and enhancement measures that can minimize adverse impacts on HMS EFH. Other information sources and examples likely exist, and many new studies are underway or in various stages of completion or publication. Accordingly, the following discussion is presented as a starting point in the identification of threats to HMS EFH and is intended to satisfy requirements of the Magnuson-Stevens Act. The habitat provisions of this FMP represent an initial step in identifying EFH and the threats to EFH, and provide a framework for continuing to focus attention on this critical area of fishery management. It is intended to stimulate further discussion, research and analyses that can improve future revisions of this document.

From the broadest perspective, fish habitat is the geographic area where the species occurs at any time during its life. Habitat can be described in terms of location; physical, chemical and biological characteristics; and time. Ecologically, habitat includes structure or substrate that focuses distribution (e.g., coral reefs, topographic highs, areas of upwelling, frontal boundaries, particular sediment types, or submerged aquatic vegetation) and other characteristics that are less distinct but are still crucial to the species' continued use of the habitat (e.g., turbidity zones, salinity, temperature or oxygen gradients).

Species use habitat for spawning, breeding, migration, feeding and growth, and for shelter from predation to increase survival. Spatially, habitat use may shift over time due to changes in life history stage, abundance of the species, competition from other species, and environmental variability in time and space. Species distributions and habitat use can be altered by habitat change and degradation resulting from human activities and impacts, or other factors. The type of habitat available, its attributes, and its functions are important to species productivity, diversity and survival.

The role of habitat in supporting the productivity of organisms has been well documented in the ecological literature, and the linkage between habitat availability and fishery productivity has been examined for several fishery species. Because habitat is an essential element for sustaining the production of a species, and therefore the fisheries based on those species, the goals of FMPs cannot be achieved if the managed species do not have sufficient quantities of suitable habitat available for each life stage.

The quantitative relationships between fishery production and habitat are very complex and no reliable models currently exist. Accordingly, the degree to which habitat alterations have affected fishery production is unknown. In one of the few studies that have been able to investigate habitat fishery productivity dynamics, Turner and Boesch (1987) examined the relationship between the extent of wetland habitats in the Gulf of Mexico and the yield of fishery species dependent on coastal bays and estuaries. They found reduced fishery stock production following wetland losses, and stock gains following increases in the areal extent of wetlands. While most of the studies examined shrimp or menhaden productivity, other fisheries show varying degrees of dependence on particular habitats and likely follow similar trends.

Accordingly, a significant threat facing fishery production is the loss of habitat due to natural and/or anthropogenic causes.

Species of the HMS fisheries utilize diverse habitats that have been identified as essential to various life stages. Many of the shark species use bays, estuaries and shallow coastal areas as crucial pupping and nursery areas. In only a few cases are there particular bottom types that can be attributed to influencing the choice of habitats, e.g., the bonnethead shark juvenile stages are associated with sand or mud bottoms. Pelagic species (or life stages), such as the pelagic sharks, tuna and swordfish, are most often associated with areas of convergence or oceanographic fronts such those found over submarine canyons, the edge of the continental shelf, or the boundary currents (edge) of the Gulf Stream. Although there is no substrate or hard structure in the traditional sense, these water column habitats can be characterized by their physical, chemical and biological parameters.

6.6.1 Fishing Activities That May Adversely Affect EFH

The Magnuson-Stevens Act requires that the fishery management councils (Councils; NMFS for Secretarial FMPs) identify adverse effects on EFH caused by fishing activities, and further requires that Councils manage the fisheries under their jurisdictions so as to minimize such impacts, to the extent practicable. The EFH regulations explain that “adverse effects from fishing may include physical, chemical, or biological alterations of the substrate, and loss of, or injury to, benthic organisms, prey species and their habitat, and other components of the ecosystem.” The regulations require that FMPs contain an assessment of the potential adverse effects of all fishing gears and practices used in waters described as EFH. The assessment must consider the relative impacts of gears on all different types of EFH identified. Special consideration is to be given to the analysis of impacts from gears that will affect Habitat Areas of Particular Concern (HAPC).

The EFH regulations also require that FMPs include management measures that minimize adverse effects on EFH from fishing, to the extent practicable. To decide if minimization of an adverse effect from fishing is practicable, the Council (NMFS) must consider: 1) whether, and to what extent, the fishing activity is adversely impacting EFH, including the fishery; 2) the nature and extent of the adverse effect on EFH; and, 3) whether the management measures are practicable, taking into consideration the long and short-term costs as well as the benefits to the fishery and its EFH, along with other appropriate factors consistent with NS 7. Councils are advised to use the best scientific information available, as well as other appropriate information sources, as available. Where information gaps are identified through the assessment process, Councils should consider the establishment of research closure areas and other measures to evaluate the impact of any fishing activity that physically alters EFH.

This section includes an assessment of fishing gears and practices that are used in the HMS fisheries, accompanied by conservation recommendations to minimize the potential impacts. Also included is a brief discussion of the scientific review of information relating to fishing impacts on habitat. In recent reviews of fishing impacts on habitat, Jennings and Kaiser (1998) and Auster and Langton (1998) characterize fishing impacts hierarchically:

impacts on structural components of habitat, effects on community structure, and effects on ecosystem processes. In this section the impacts of HMS fishing activities will be addressed in the same format, followed by comments on non-HMS fishing impacts on HMS EFH, and also the identification of research priorities to provide additional information that can be used to improve future amendments to the FMP EFH provisions.

Physical Impacts of HMS Fishing Gears on EFH

The following gears have been identified in this FMP for the HMS fisheries:

Atlantic Highly Migratory Species

Directed Fishery	**Approved Gear**
Atlantic Swordfish:	
A. Handgear fishery	A. Rod and reel, handline, harpoon
B. Longline fishery	B. Longline
Atlantic Sharks:	
A. Hook and line fishery	A. Rod and reel, handline, bandit gear
B. Longline fishery	B. Longline
C. Drift Gillnet fishery	C. Drift Gillnet.
Atlantic Tuna:	
A. General fishery	A. Rod and reel (including downriggers), handline, harpoon, bandit gear
B. Purse seine fishery	B. Purse seine
C. Longline fishery	C. Longline
D. Harpoon fishery	D. Harpoon
E. Angling fishery	E. Rod and reel (including downriggers),
F. Charter/Headboat	F. Rod and reel (including downriggers), bandit gear, handline
G. Trap handline	G. Poundnet, fish weir

Generally, the target species of the HMS fishery management units are associated with hydrographic structures of the water column, e.g., convergence zones or boundary areas between different currents. Because of the magnitude of water column structures and the processes that create them, there is little effect that can be detected from the HMS fishing activities undertaken to pursue these animals. There are, however, some impacts that can be manifest on the biological or chemical characteristics of some of these sites, e.g., excess dead discards causing increased biological oxygen demand (BOD). For fisheries in which gear does contact the substrate, there is certainly the potential for disturbance of the habitat. An analysis of the effects and the impacts they may have on the associated fisheries is complicated by the fact that scientists are not certain of the particular characteristics that draw the fish to these habitats.

Of the approved gears that are used in the HMS fisheries, only bottom longlines, principally targeting large coastal sharks, can contact the bottom substrate. Gear could become hung or entangled on various elements of the substrate including rocks, boulders, hard- or live-bottoms, and hard or soft corals. In instances where target species are attracted to the habitat due to hydrographic characteristics, i.e., up-welling, convergences, etc., the scale of impact from careless placement of bottom longlines is probably not of sufficient magnitude to affect the characteristics of the habitat. If, however, the fish are attracted because of prey resources, the prey may be dependent on habitat characteristics that could be altered at these scales. NMFS recommends that fishermen take appropriate measures to identify bottom obstructions and "hangs" and avoid setting gear in areas where it may become entangled and potentially disrupt benthic habitats. If gear is lost, diligent efforts should be made to recover the lost gear to avoid further fouling (disturbance) of the underwater habitat through "ghost fishing."

Population and Ecosystem Impacts of Removing Target Species

There is currently a great deal of interest in the ecosystem level effects of removing apex predators from aquatic systems. Although there has not been extensive research in this field, there are a few examples where population or ecosystem effects have been inferred from fishing activities. Branstetter and Burgess (1997) suggest that increased survival of young tiger, dusky and sandbar sharks may be due to the removal of large sharks that prey upon these juveniles. There is some evidence that removal of large sharks in coastal waters of South Africa has resulted in a proliferation of small shark species (C. Buxton, pers. comm.). Overfishing of cod in the northwest Atlantic has led to apparent "species replacement" where dogfish (sharks) have proliferated and assumed the ecological role previously held by cod. At the present time it is believed that it may be difficult if not impossible to reverse the trend and re-establish cod populations.

Natural ecosystems maintain a dynamic equilibrium that will ensure stability, within natural variation, as long as ecological disturbance is neither too intense nor too frequent. Removal of one trophic level (e.g., apex predators) could be a major disturbance to an ecosystem. At moderate levels of disturbance, populations and ecosystems are likely able to compensate and maintain their biological integrity (Smith, 1990). Continued high rates of removal of tuna, swordfish and shark adults and late juveniles (top predators) might constitute a frequent and intense disturbance with the capacity to induce large-scale changes in the biological characteristics of the habitat. Continued disturbance could result in unforeseen ecological changes, detrimental to the long-term productivity of the HMS species, resulting from changes in the biological characteristics of their EFH. The time/area closures implemented in this FMP (Chapter 3) to reduce discards of bluefin tuna could be a risk-averse method to avoid changes in the biological characteristics of the HMS EFH and to help ensure the biological integrity of the habitats. Research into cascading ecological effects from apex predator removal should also be encouraged.

Impacts on HMS EFH from non-HMS Fishing Gears and Practices

Because some HMS use both estuarine and coastal inshore habitats, their EFH may be negatively impacted by fisheries that target species other than HMS. These fisheries may be either state or federally managed. In particular, shark pupping and nursery habitats are subjected to fishing impacts from gears of other fisheries, e.g., shrimp trawling, but the degree to which particular parameters are altered by these gears is, as yet, unquantified. Trawl fisheries that scrape the substrate, disturb boulders and their associated epiphytes or epifauna, re-suspend sediments, flatten burrows and disrupt seagrass beds have the potential to alter the habitat characteristics that are important for survival of early life stages of many targeted and non-targeted species.

The degree of impact and long term habitat modification depends on the severity and frequency of the impacts as well as the amount of recovery time between impacts (Auster and Langton, 1998). The extent to which particular parameters are altered by trawl gear is somewhat dependent on the configuration of the gear and the manner in which the gear is fished. Additional efforts are required to study HMS EFH areas that are fished for non-HMS species and identify fishing gears that impact habitat. In this regard, coordination efforts should be undertaken with the respective Councils to identify potential common areas. Research into the frequency of disturbance and the changes induced in the habitat are of primary importance. A better understanding of the habitat characteristics that influence the abundance of managed species within those habitats is needed in order to understand the effects of fishing activities on habitat suitability for HMS.

Besides altering the physical characteristics of EFH, other fisheries may remove prey species that make up the necessary biological components of HMS EFH. As an example, development or expansion of a squid fishery off the Atlantic coast has the potential to degrade the quality of EFH for tuna and swordfish since many of these species consume a high percentage of squid in their diets. Research into the dynamics of these interactions between fisheries should be investigated for future consideration. If there is evidence that another fishery is depleting the resources associated with the EFH of HMS, the issue of resource allocation will need to be addressed with the appropriate Council(s).

Additionally, other fisheries may actively remove habitat components that are important to the integrity of HMS EFH. Many of these impacts have been addressed in other fishery management plans (e.g., SAFMC, 1998; GMFMC, 1998) that focus on restricting the removal of attached species such as corals or kelp that provide essential structure in their respective habitats; however, for pelagic species other biological components must be considered. Some tuna and swordfish life stages have been found to be associated, or to co-occur, with floating mats of the brown algae, *Sargassum* sp. The mats are pelagic and are moved extensively by winds and currents. They are frequently found in convergence zones, windrows, or at current boundaries - areas that are EFH for many of the HMS life stages. Whether the floating mats serve as shelter, act as a source of prey (because of the abundance of prey species associated with them), serve as a means of camouflage, or serve some other biological function is not entirely clear. It is a biological component that may focus, particularly on the small scale, the distribution of certain life stages of tuna and swordfish, and it should be maintained in its habitat. Under the Magnuson-Stevens Act definitions, harvesting of *Sargassum* would qualify as a "fishing activity." As such, NMFS has been urged by the HMS Advisory Panel to make strong recommendations against the harvest, possession or landing of *Sargassum* within the U.S. EEZ. In order for this recommendation to be enforceable, it must also include recommendations that no *Sargassum* can be possessed or landed within the United States since it would be impossible to verify if this *Sargassum* was harvested outside the EEZ and simply transported back into U.S. waters for landing. Harvest of *Sargassum* is under the jurisdiction of the South Atlantic Fishery Management Council and will be phased out under the Council's new FMP.

EFH Conservation Recommendations

The EFH regulations require that Councils act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing practice is having an identifiable adverse effect on EFH, based on the assessment of fishing gears on EFH.

At this time, there is no evidence that physical effects caused by fishing under this FMP are adversely affecting HMS EFH to the extent that detrimental effects can be identified on the habitat or the fisheries. The following two conservation recommendations, discussed above as NMFS' suggestions, should help to mitigate any impacts that are currently occurring but unverified:

- Fishermen should take appropriate measures to identify bottom obstructions and avoid setting gear in areas where it may become entangled.

- If gear is lost, diligent efforts should be undertaken to recover the lost gear.

In addition, this FMP discusses the use of time/area closures as a possible management option to reduce the take of juvenile swordfish, tuna, and billfish (Chapter 3). Specifically, one time/area closure is being implemented under this FMP in the mid-Atlantic in order to reduce bluefin tuna discards during the month of June. Besides serving as a tool to reduce bycatch and rebuild stocks, seasonal closures could also help maintain the biological integrity of HMS EFH and reduce the chance of altering the biological characteristics of EFH. By preserving more of the age structure in the population and a diversity of trophic levels, this measure could lend added stability to the ecosystem upon which the HMS fisheries depend. From an EFH perspective, the alternative of time/area closures is seen as a desirable step toward conserving and enhancing HMS EFH. As such, NMFS recommends time/area closures as a conservation measure for the protection of adult and juvenile HMS EFH.

Within the Atlantic and Caribbean there are currently two areas that have been closed, or are proposed to be closed, to some or all fishing in order to reduce gear impacts on fisheries and their habitats. The first is an area designated as the Oculina Bank Habitat of Particular Concern (HAPC), located 15 nautical miles east of Ft. Pierce, Florida. This area overlaps with the EFH of a number of HMS. The South Atlantic Fishery Management Council has restricted certain fishing gears here in order to protect this unique habitat assemblage. Because there is evidence of extensive fishing related habitat destruction and related decreases in fishery abundance, the use of bottom longline, bottom trawl, dredge, pot, and trap gears is restricted within this HAPC. Of these gears, only bottom longlines are used in the HMS fishery (for sharks). Although the primary concern for the Oculina Bank is to maintain the integrity of the branching hard coral *Oculina varicosa*, maintaining the integrity of the ecosystem is also an important consideration, as the corals form the basis of a highly diverse resident invertebrate community which, in turn, supports large populations of fishes (including HMS).

The second area is the Hind Bank, a coral reef ecosystem located in the Caribbean southwest of St. Thomas, USVI. Coral reef communities within the region, susceptible to damage by overfishing, are showing signs of stress. Understanding the complexity of the ecosystem and the necessity of conserving and managing both the fish species and the coral assemblage that provides structural habitat, the Caribbean Fishery Management Council is thereby proposing the establishment of the Hind Bank Marine Conservation District (MCD) in an attempt to curtail future problems with the associated fisheries. This measure would preclude all fishing activity throughout the year in order to conserve, protect and manage the coral reef habitat and associated resources, particularly the coral *Monastrea annularis* identified as EFH for spawning red hind.

Limited assess is another means of conserving HMS EFH. Under this FMP, implementation of limited access to the swordfish, shark and pelagic longline fisheries (Chapter 4) has the potential to lessen fishing pressure on habitats by reducing the number of fishermen that could harvest these resources. Limited access may also prevent some fishing by individuals less familiar with the gear and/or habitats who may be more likely to damage the habitat through improper setting of gear in EFH.

Additional study is recommended to more adequately identify adverse impacts and to quantify impacts currently occurring. Any inshore areas that are closed to fishing in order to conserve pupping and juvenile habitats would be ideal locations to study the effects of gear impacts on EFH. Research in these areas is strongly advocated, and further evaluations of fishing impacts on HMS habitat will be undertaken as more research is conducted and information becomes available. Information will be reviewed annually to assess the state of knowledge in this field (Section 6.8). Future revisions of the habitat (and EFH) provisions in this FMP will include any new information on the impacts of fishing activities on fish habitat, including EFH.

6.6.2 Non-fishing Threats to EFH

Section 600.815 (a)(5) of the EFH regulations requires that FMPs identify non-fishing related activities that may adversely affect EFH of managed species, either quantitatively or qualitatively, or both. In addition, Section 600.815 (a)(7) of the regulations requires that FMPs recommend conservation measures describing options to avoid, minimize, or compensate for the adverse effects identified. As the jurisdiction and the EFH of this Secretarial FMP overlaps with the EFH identified by the respective Councils of the eastern United States, the threats to EFH and conservation measures compiled for this document are a synthesis of those listed in the Councils' EFH amendments. The information in this section has been adapted, with permission, from EFH amendments prepared by the Mid-Atlantic

(MAFMC, 1998), South Atlantic (SAFMC, 1998) and Gulf of Mexico (GMFMC, 1998) Councils. Original sources of information are cited in those documents.

Broad categories of activities that may adversely affect HMS EFH include, but are not limited to: 1) actions that physically alter structural components or substrate, e.g., dredging, filling, excavations, water diversions, impoundments and other hydrologic modifications; 2) actions that result in changes in habitat quality, e.g., point source discharges, activities that contribute to non-point source pollution and increased sedimentation, introduction of potentially hazardous materials, or activities that diminish or disrupt the functions of EFH. If these actions are persistent or intense enough, they can result in major changes in habitat quantity as well as quality, conversion of habitats, or in complete abandonment of habitats by some species.

Estuarine, coastal, and offshore waters are used by humans for a variety of purposes that often result in degradation of these and adjacent environments, posing threats, either directly or indirectly, to the associated biota. These effects, either alone in combination with (cumulative) effects from other activities within the ecosystem, may contribute to the decline of some species or biological components of the habitat. In many cases such effects may be demonstrated, but they are often difficult to quantify.

Pollutants (e.g., heavy metals, oil and grease, excess nutrients, improperly treated human and animal wastes, pesticides, herbicides and other chemicals) can be introduced into the aquatic environment through a number of routes, including point sources, non-point sources and atmospheric deposition. These types of contaminants have been demonstrated to affect finfish and invertebrates by altering the growth, visual acuity, swimming speed, equilibrium, feeding rate, response time to stimuli, predation rate, spawning seasons, migration routes, and resistance to disease and parasites. In addition to the introduction of contaminants that cause direct effects on animal physiology, point source discharges also affect essential habitat characteristics such as water flow, temperature, pH, dissolved oxygen, salinity, and other parameters that affect habitat suitability for individuals, populations and communities. The synergistic effects of multiple discharge components such as heavy metals and various chemical compounds are not well understood but are increasingly the focus of research efforts. More subtle effects of contaminants, such as endocrine disruption in aquatic organisms and reduced ability to reproduce or compete for food, are also being identified and investigated.

Non-point source runoff may have a more significant impact on coastal water quality, particularly since tighter controls on point source discharges have recently been instituted. Activities that tend to increase the input of contaminants to aquatic environments through non-point sources include coastal development, urbanization, certain agriculture and silviculture practices, marina and port development, commercial and recreational boating, and hydromodification. Related activities, such as the use of septic systems and improper disposal or treatment of wastes, can contribute biological contaminants, as well. Many of these activities can result in large quantities of pesticides, nutrients, and bacteria or pathogens in coastal waters. Excess nutrification is one of the greatest sources of coastal water contamination. Nutrient enrichment can lead to noxious algal blooms, fish kills, and oxygen depletion (as hypoxic or anoxic events). Researchers have found reduced or stressed fisheries populations to be common in areas where hypoxia occurs.

As required under the EFH regulations, the following discussion identifies activities having the potential to adversely affect HMS EFH. In many cases these activities are regulated under particular statutory authorities. As long as they are regulated within those guidelines, their potential to adversely affect EFH may be reduced, although not necessarily eliminated. Many of the standards that are used to regulate these activities are based on human health needs and do not consider long-term impacts on fish and fish habitats. Additionally, if the activity fails to meet or is operated outside its permitted standards, it may adversely affect EFH. The EFH regulations require NMFS and the Councils to identify actions with the **potential** to adversely affect EFH, including its biological, chemical and physical characteristics. The EFH regulations also recommend the examination of cumulative impacts on EFH, it is possible that many permitted actions, operating within their regulatory bounds, may cause adverse impacts on EFH. The following sections list a broad range of activities to ensure that their potential to adversely affect HMS EFH has been identified.

The review of habitat use undertaken for this chapter identified both benthic and water column habitats in coastal, estuarine and offshore areas as EFH, although in many cases the particular habitat characteristics that control species habitat use are not clearly identified. Many of these factors appear to be related to water quality (e.g., temperature, salinity, dissolved oxygen). Therefore, water quality degradation has been a primary focus in this section. When analyzing the impacts that water quality changes can have on HMS EFH, it is important to examine all habitats. EFH for HMS includes offshore areas, but even these distant habitats are affected by actions that originate in coastal habitats (both terrestrial and aquatic) and adjacent estuaries. Many of the HMS aggregate over submarine canyons or along river plumes; these physiographic features can serve as conduits for currents moving from inshore out across the continental shelf and slope, while carrying and redistributing contaminants from the nearshore realm to offshore habitats. Until the precise zones of influence from various river and coastal discharges can be delineated, a precautionary approach should be taken in order to protect the integrity of HMS EFH and the sustainability of the HMS fisheries.

In addition to identifying activities with the potential to adversely affect EFH, the Magnuson-Stevens Act and the EFH regulations require the inclusion of measures to conserve and enhance EFH. Each activity discussed below is followed by conservation measures to avoid, minimize or mitigate its adverse effects on EFH. These include examples of both general and specific conservation measures that might be appropriate for NMFS to include as part of its conservation recommendations to Federal and state agencies on activities similar to those discussed below. In some cases, the measures are based on site-specific activities; in others they represent broad policy-type guidelines. It should be understood that during EFH consultations, each project will be evaluated on its merits, and the threat to EFH and appropriate conservation measures will be assessed at that time. The Federal action agency with the statutory authority to regulate the proposed action, weighs the recommendations of all commenters and decides on the appropriate action, modifications or mitigation before proceeding with a project. The conservation measures included in this

FMP are meant to be examples of NMFS recommendations that might be made regarding particular projects. They are intended to assist Federal and state agencies and other entities during the planning process when minimization of adverse impacts on EFH can most effectively be incorporated into project designs and goals.

6.6.2.1 Marine Sand and Minerals Mining

Mining for sand (e.g., for beach nourishment projects), gravel, and shell stock in estuarine and coastal waters can result in water column effects by changing circulation patterns, increasing turbidity, and decreasing oxygen concentrations at deeply excavated sites where flushing is minimal. Ocean extraction of mineral nodules is a possibility for some non-renewable minerals now facing depletion on land. Such operations are proposed for the continental shelf and the deep ocean proper. Deep borrow pits created by mining may become seasonally or permanently anaerobic. Marine mining also elevates suspended materials at mining sites, creating turbidity plumes that may move several kilometers from these sites. Resuspension of sediments can affect water clarity over wide areas, and could also potentially affect pelagic eggs and larvae. In addition, resuspended sediments may contain contaminants such as heavy metals, pesticides, herbicides, and other toxins.

Conservation measures:

- Sand mining and beach nourishment should not be allowed in HMS EFH during seasons when HMS are utilizing the area, particularly during spawning seasons.

- Gravel extraction operations should be managed to avoid or minimize impacts to the bathymetric structure in estuarine and nearshore areas.

- An integrated environmental assessment, management, and monitoring program should be a part of any gravel or sand extraction operation, and encouraged at federal and state levels.

- Planning and design of mining activities should avoid significant resource areas important as HMS EFH.

- Mitigation and restoration should be an integral part of the management of gravel and sand extraction policies.

6.6.2.2 Offshore Oil and Gas Operations

Offshore oil and gas operations (exploration, development, production, transportation and decommissioning) pose a significant level of potential threat to marine, coastal and estuarine ecosystems. Exploration and recovery operations may cause substantial localized bottom disturbance. However, more pertinent to HMS is the threat of contaminating operational wastes associated with offshore exploration and development, the major operational wastes being drilling muds and cuttings and formation waters. In addition, there are hydrocarbon products, well completion and work-over fluids, spill clean-up chemicals, deck drainage, sanitary and domestic wastes, ballast water, and the large volume of unrefined and refined products that must be moved within offshore and coastal waters. Potential major contaminants used in oil and gas operations may be highly saline; have low pH; contain suspended solids, heavy metals, crude oil compounds, and organic acids; or may generate high biological and chemical oxygen demands. Also, accidental discharges of oil - crude, diesel and other oil products - and chemicals can occur at any stage of exploration, development, or production, the great majority of these being associated with product transportation activities. Blowouts and associated oil spills can occur at any operational phase when improperly balanced well pressures result in sudden, uncontrolled releases of petroleum hydrocarbons. To remove fixed platforms, explosives are frequently used. All of these activities result in harmful effects on marine water quality as well as the biota in the vicinity.

In the Gulf of Mexico, Outer Continental Shelf (OCS) oil and gas operations are extending to deeper and deeper waters, throughout which HMS are known to range. Locations such as the De Soto Canyon area in the northern Gulf and the Blake Plateau north of the Bahamas repeatedly appear in the analysis of HMS EFH as highly productive areas important to many of these species. Oil and gas production in these areas should be discouraged because of the potential impact on HMS EFH in these areas.

Considerable documentation exists that highlights the benefits of offshore production platforms as artificial reefs that attract numerous species of fishes, including HMS. It is likely that the attraction of these species to the platforms increases the potential for exposure to contaminants they may release into the aquatic environment.

Conservation measures

- A plan should be in place to avoid the release of hydrocarbons, hydrocarbon-containing substances, drilling muds, or any other potentially toxic substance into the aquatic environment. Storage of these materials should be in enclosed tanks whenever feasible or, if not, in lined mud pits or other approved sites. Equipment should be maintained to prevent leakage. Catchment basins for collecting and storing surface runoff should be included in the project design.

- Exploration/production activities and facilities should be designed and maintained in a manner that will maintain natural water flow regimes, avoid blocking surface drainage, and avoid erosion in adjacent coastal areas.

- Activities should avoid wetlands. Drilling should be conducted from uplands, existing drill sites, canals, bayous or deep bay waters (greater than six feet), wherever possible, rather than dredging canals or constructing board roads. When wetland use is unavoidable, work in previously disturbed wetlands is preferable to work in high quality or undisturbed wetlands. If this is not possible, temporary roads (preferably board roads) to provide access are more desirable than dredging canals because roads generally impact less acreage and are easier to restore than canals. If the well is a producer, the drill pad should be reduced to the minimum size necessary to conduct production activities and the disturbed area should be restored to pre-project conditions.

- Upon completion or abandonment of wells in wetlands, all unnecessary equipment should be removed and the area restored to pre-project elevations. The well site, various pits, levees, roads and other work areas should be graded to pre-project marsh elevations and then restored with indigenous wetland vegetation. Abandoned canals frequently need plugging and capping with erosion-resistant material at their origin to minimize bank erosion and to prevent saltwater intrusion. In addition, abandoned canals will frequently need to be backfilled to maximize fish and wildlife production in the area and to restore natural sheet flows. Spoil banks containing uncontaminated materials should be backfilled into borrow areas or breached at regular intervals to re-establish hydrological connections.

- In open bays maximum use should be made of existing navigable waters already having sufficient width and depth for access to the drill sites.

- An oil spill response plan should be developed and coordinated with Federal and state resource agencies.

- Activities on the OCS should be conducted so that petroleum-based substances such as drilling muds, oil residues, produced waters, or other toxic substances are not released into the water or onto the sea floor: drill cuttings should be shunted through a conduit and discharged near the sea floor, or transported ashore or to less sensitive, NMFS-approved offshore locations; drilling and production structures, including pipelines, generally should not be located within one mile of the base of a live reef.

- Prior to pipeline construction, less damaging, alternative modes of oil and gas transportation should be explored.

- State natural resource agencies should be involved in the preliminary pipeline planning process to prevent violations of water quality and habitat protection laws and to minimize impact of pipeline construction and operation on aquatic resources.

- Pipeline alignments should be located along routes that minimize damage to marine and estuarine habitats. Buried pipelines should be examined periodically for maintenance of adequate earthen cover.

- All vessels transporting fuels and other hazardous materials should be required to carry equipment to contain and retrieve the spill. Dispersants shall not be used to clean up fuels and hazardous materials unless approved by the EPA/Coast Guard and fishery agencies.

- NPDES permit conditions such as those relating to dissolved oxygen, temperature, impingement and entrainment, under the Clean Water Act should be monitored and strictly enforced in areas that could affect HMS EFH.

- NPDES permits should be reviewed every five years for all energy production facilities.

6.6.2.3 Coastal Development

Coastal development activities include urban, suburban, commercial, and industrial construction, along with development of corresponding infrastructure. These activities may result in erosion and sedimentation, dredging and filling (see following sub-section), point and non-point source discharges of nutrients, chemicals, and cooling water into streams, rivers, estuaries and ocean waters. Industrial point source discharges result in the contamination of water and degradation of water quality by introducing organics and heavy metals or altering other characteristics such as pH and dissolved oxygen. Improperly treated sewage treatment effluent has been shown to produce changes in water quality as a result of chlorination and increased contaminant loading, including solids, phosphorus, nitrogen and other organics, and human pathogens and parasites. Non-point source pollution - that which results from land runoff, atmospheric deposition, drainage, groundwater seepage, or hydrologic modification - results in the deposition of pathogens, nutrients, sediments, heavy metals, oxygen demanding substances, road salts, hydrocarbons and other toxics.

Coastal development can also lead to the destruction of coastal wetlands, resulting in the elimination of protective buffer zones that serve to filter sediments, nutrients, and contaminants - such as heavy metals and pesticides - that are transported to the coastal zone in ground and surface waters. In addition, hydrological modifications associated with coastal development alter freshwater inflow to coastal waters, resulting in changes in salinity, temperature, and nutrient regimes, and thereby contributing to further degradation of estuarine and nearshore marine habitats. The variety of pollutants and the severity of their effects from coastal development activities depend upon a number of factors, such as the nature of the construction, physical characteristics of the site involved, and proximity of the pollutant source to the coastline. However, all of these factors ultimately serve to degrade estuarine and coastal water quality to some degree in terms of dissolved oxygen levels, salinity concentrations, and contaminants.

Conservation measures

- Adverse impacts resulting from construction should be avoided whenever practicable alternatives are identified. For those impacts that cannot be avoided, minimization through implementation of Best Management Practices (BMPs) should be employed. For those impacts that can neither be avoided nor minimized, compensation through replacement of equivalent functions and values should be required.

- Coastal development traditionally has involved dredging and filling of shallows and wetlands, hardening of shorelines, clearing of riparian vegetation, and other activities that adversely affect the habitats of living marine resources. Mitigative measures should be required for all development activities with the potential to degrade HMS

EFH, whether conducted within the EFH or in adjacent areas that influence HMS EFH.

- Destruction of wetlands and shallow coastal water habitats should not be permitted in areas adjacent to HMS EFH. Mitigating or compensating measures should be employed where destruction is unavoidable. Project proponents should demonstrate that project implementation will not negatively affect HMS, their habitat, or their food sources.

- Flood control projects in waterways draining into EFH should be designed to include mitigative measures and constructed using BMPs. For example, stream relocation and channelization should be avoided whenever practicable. However, should no practicable alternatives exist, relocated channels should be of comparable length and sinuosity as the natural channels they replace to maintain the quality of water entering receiving waters (i.e., HMS EFH).

- Watershed protection/site development should be encouraged. Comprehensive planning for development on a watershed scale (and for small-scale site development as well) should be undertaken, including planning and designing to protect sensitive ecological areas, minimizing land disturbances and retaining natural drainage and vegetation whenever possible. To be truly effective, watershed planning efforts should include existing facilities even though they are not subject to EFH consultation.

- Pollution prevention activities, including techniques and activities to prevent non-point source pollutants from entering surface waters, should be implemented. Primary emphasis should be placed on public education to promote methods for proper disposal and/or recycling of hazardous chemicals, management practices for lawns and gardens, onsite disposal systems (OSDSs), and commercial enterprises such as service stations and parking lots.

- Construction erosion/sediment control measures should be used to reduce erosion and transport of sediment from construction sites to surface waters. A sediment and erosion control plan should be developed and approved prior to land disturbance.

- Runoff from new development should be managed so as to meet two conditions: 1) the average annual total suspended solids loadings after construction is completed are no greater than pre-development loadings; and 2) to the extent practicable, post-development peak runoff rate and average volume are maintained at levels that are similar to pre-development levels.

- Construction site chemical control measures should address the transport of toxic chemicals to surface water by limiting the application, generation, and migration of chemical contaminants (i.e., petrochemicals, pesticides) and providing proper storage and disposal.

- New OSDSs should be built to reduce nutrient/pathogen loadings to surface waters. OSDSs should be designed, installed and operated properly and to be situated away from open waterbodies and sensitive resources such as wetlands, and floodplains. Protective separation between the OSDS and the groundwater table should be established. The OSDS unit should be designed to reduce nitrogen loadings in areas where surface waters may be adversely affected. Operating OSDSs should prevent surface water discharges and reduce pollutant loadings to ground water. Inspection at regular intervals and repair or replacement of faulty systems should occur.

- Roads, highways, bridges and airports should be situated away from areas that are sensitive ecosystems and susceptible to erosion and sediment loss. The siting of such structures should not adversely impact water quality, should minimize land disturbances, and should retain natural vegetation and drainage features.

- Construction projects of roads, highways, bridges and airports should implement approved erosion and sediment control plans prior to construction to reduce erosion and improve retention of sediments onsite during and after construction.

- Construction site chemical control measures for roads, highways, and bridges should limit toxic and nutrient loadings at construction sites by ensuring the proper use, storage, and disposal of toxic materials to prevent significant chemical and nutrient runoff to surface waters.

- Operation and maintenance activities for roads, highways, bridges, and airports should be developed so as to reduce pollutant loadings to receiving waters during operation and maintenance.

- Runoff systems should be developed for roads, highways, bridges, and airports to reduce pollutant concentrations in runoff from existing roads, highways, and bridges. Runoff management systems should identify priority pollutant reduction opportunities and schedule implementation of retrofit projects to protect impacted areas and threatened surface waters.

- The planning process for new and maintenance channel dredging projects should include an evaluation of the potential effects on the physical and chemical characteristics of surface waters that may occur as a result of the proposed work, and should reduce undesirable impacts. When the operation and maintenance programs for existing modified channels are reviewed, they should identify and implement any available opportunities to improve the physical and chemical characteristics of surface waters in those channels.

- Bridges should be designed to include collection systems which convey surface water runoff to land-based sedimentation basins.

- Sewage treatment discharges should be treated to meet state water quality standards. Implementation of up-to-date methodologies for reducing discharges of biocides (e.g., chlorine) and other toxic substances is encouraged.

- Use of land treatment and upland disposal/storage techniques of solid waste from sewage treatment should be implemented where possible. Use of vegetated wetlands as natural filters and pollutant assimilators for large scale wastewater discharges should be limited to those instances where wetlands have been specifically created for this purpose. The use of such constructed wetlands for water treatment should be encouraged wherever the overall environmental and ecological suitability of such an action can been demonstrated.

- Sewage discharge points in coastal waters should be located well away from critical habitats. Proposals to locate outfalls in coastal waters must be accompanied by hydrographic studies that demonstrate year round dispersal characteristics and provide proof that effluents will not reach or affect fragile and productive habitats.

- Dechlorination facilities or lagoon effluent holding facilities should be used to destroy chlorine at sewage treatment plants.

- No toxic substances in concentrations harmful (synergistically or therwise) to humans, fish, wildlife, and aquatic life should be discharged. The EPA's Water Quality Criteria Series should be used as a guideline for determining harmful concentration levels. Use of the best available technology to control industrial waste water discharges should be required in areas adjacent to habitats essential to HMS. Any new potential discharge that will influence HMS EFH must be shown not to have a harmful effect on HMS or their habitat.

- The siting of industries requiring water diversions and large-volume water withdrawals should be avoided in areas influencing HMS EFH. Project proponents should demonstrate that project implementation will not negatively affect HMS, their EFH, or their food supply. Where such facilities currently exist, best management practices should be employed to minimize adverse effects on the aquatic environment.

- All NPDES permits should be reviewed and strictly enforced in areas affecting HMS EFH.

- Hazardous waste sites should be cleaned up (i.e., remediated) to prevent contaminants from entering aquatic food chains. Remedial actions affecting aquatic and wetland habitats should be designed to facilitate restoration of ecological functions and values.

6.6.2.4 Dredging and Disposal of Dredge Material

Dredging operations occur in estuaries, nearshore areas, and offshore in order to maintain certain areas for activities such as shipping, boating, construction of infrastructure (e.g., offshore oil and gas pipelines), and marine mining. Disposal of the dredged material takes place in designated open water disposal areas, often near the dredge site. These operations result in negative impacts on the marine environment. Of particular concern regarding HMS EFH is the temporary degradation of water quality due to the resuspension of bottom materials, resulting in water column turbidity, potential contamination due to the release of toxic substances (metals and organics), and reduced oxygen levels due to the release of oxygen-consuming substances (e.g., nutrients, sulfides). Even with the use of approved practices and disposal sites, ocean disposal of dredged materials is expected to cause environmental harm since contaminants will continue to be released, and localized turbidity plumes and reduced oxygen zones may persist.

Conservation measures

- Best engineering and management practices (e.g., seasonal restrictions, modified dredging methods, and/or disposal options) should be employed for all dredging and in-water construction projects. Such projects should be permitted only for water dependent purposes when no feasible alternatives are available. Mitigating or compensating measures should be employed where significant adverse impacts are unavoidable. Project proponents should demonstrate that project implementation will not negatively affect HMS, their EFH, or their food sources.

- Project guidelines should make allowances to cease operations or take additional precautions to avoid adversely affecting HMS EFH during seasons when sensitive HMS life stages might be most susceptible to disruption (e.g., seasons when spawning is occurring).

- When projects are considered and in review for open water disposal permits for dredged material, Federal permitting agencies should identify the direct and indirect impacts such projects may have on HMS EFH.

- Uncontaminated dredged material may be viewed as a potentially reusable resource if properly placed and beneficial uses of these materials should be investigated. Materials that are suitable for beach nourishment, marsh construction or other beneficial purposes should be utilized for these purposes as long as the design of the project minimizes impacts on HMS EFH.

- “Beneficial Use” proposals in areas of HMS EFH should be compatible with existing uses by HMS. If no beneficial uses are identified, dredged material should be placed in contained upland sites. The capacity of these disposal areas should be used to the fullest extent possible. This may necessitate dewatering of the material or increasing the elevation of embankments to augment the holding capacity of the site. Techniques could be applied that render dredged material suitable for export or for use in re-establishing wetland vegetation.

- No unconfined disposal of contaminated dredge material should be allowed in HMS EFH.

- Disposal sites should be located in uplands when possible.

6.6.2.5 Agriculture (and Silviculture)

Agricultural and silvicultural practices can affect estuarine, coastal and marine water quality through nutrient enrichment and chemical contamination from animal wastes, fertilizers, pesticides and other chemicals via non-point source runoff or via drainage systems that serve as conduits for contaminant discharge into natural waterways. In addition, uncontrolled or improper irrigation practices can contribute to non-point source pollution, and may exacerbate contaminant flushing into coastal waters. Major impacts also include nutrient over-enrichment with subsequent deoxygenation of surface waters, algal blooms - which can also produce hypoxic or anoxic conditions - and stimulation of toxic dinoflagellate growth. Excessively enriched waters often will not support fish, and also may not support food web assemblages and other ecological assemblages needed to sustain desirable species and populations. Agricultural activities also increase sediment transport in adjacent water bodies, resulting in high turbidity. Many of these same concerns may apply to silviculture, as well.

Conservation measures

- Federal agencies, in conjunction with state agencies, should establish and approve criteria for vegetated buffer strips in agricultural areas adjacent to estuarine and coastal HMS EFH in order to minimize pesticide, fertilizer, and sediment loads to these areas critical for HMS survival. The effective width of these vegetated buffer strips should vary with the slope of the terrain and soil permeability.

- Concerned Federal agencies (e.g., Natural Resources Conservation Service) should conduct or contribute to programs and demonstration projects to educate farmers on improved agricultural practices that would minimize the use and wastage of pesticides, fertilizers, and top soil, and reduce the adverse effects of these materials on HMS EFH.

- Delivery of sediment from agricultural lands to receiving waters should be minimized. Land owners have a choice of one of two approaches: 1) apply the erosion component of the U.S. Department of Agriculture's Conservation Management System through such practices as conservation tillage, strip cropping, contour farming, and terracing; or 2) design and install a combination of practices to remove settleable solids and associated pollutants in runoff for all but the largest storms.

- New and existing confined animal facilities should be designed to limit discharges to waters of the United States by storing wastewater and runoff caused by all storms up to and including the 25-year frequency storms. For smaller existing facilities, the management systems that collect solids, reduce contaminant concentrations, and reduce runoff should be designed and implemented to minimize the discharge of contaminants in both facility wastewater and runoff caused by all storms up to and including 25-year frequency storms.

- Stored runoff and solids should be managed through proper waste utilization and the use of disposal methods which minimize impacts to surface and ground water.

- Development and implementation of comprehensive nutrient management plans should be undertaken, including development of a nutrient budget for the crop, identification of the types and amounts of nutrients necessary to produce a crop based on realistic crop yield expectations, and an identification of the environmental hazards of the site.

- Pesticide and herbicide management should minimize water quality problems by reducing pesticide use, improving the timing and efficiency of application (not within 24 hours of expected rain or irrigation), preventing backflow of pesticides into water supplies, and improving calibration of pesticide spray equipment. Improved methods should be used such as integrated pest management (IPM) strategies. IPM strategies include evaluating current pest problems in relation to the cropping history, previous pest control measures, and applying pesticides only when an economic benefit to the producer will be achieved (i.e., application based on economic thresholds). If pesticide applications are necessary, pesticides should be selected to minimize environmental impacts such as persistence, toxicity, and leaching potential.

- Livestock grazing should protect sensitive areas, including streambanks, wetlands, estuaries, ponds, lake shores, and riparian zones. Protection is to be achieved with improved grazing management that reduces the physical damage and direct loading of animal waste and sediment to sensitive areas, i.e., by restricting livestock access or providing stream crossings.

- Upland erosion should be reduced by either applying the range and pasture components of a Conservation Management System, or maintaining the land in accordance with the activity plans established by either the Bureau of Land Management or the Forest Service. Such techniques include the restriction of livestock from sensitive areas through locating salt, shade, and alternative drinking sources away from sensitive areas, and providing livestock stream crossings.

- Irrigation systems that deliver necessary quantities of water yet reduce non-point pollution to surface waters and groundwater should be developed and implemented.

- BMPs should be implemented to minimize habitat impacts when agricultural ditches are excavated through wetlands that drain to HMS EFH.

- NPDES/SPDES permits, in consultation with state fishery agencies, should be required for agricultural ditch systems that discharge into areas adjacent to HMS EFH.

6.6.2.6 Aquaculture and Mariculture

Aquaculture is an expanding industry in the United States, with most facilities located in farmland, tidal, intertidal and coastal areas. Aquaculture related impacts that adversely affect the chemical and biological nature of coastal ecosystems include the discharge of excessive waste products and the release of exotic organisms and toxic substances. Problems resulting from the introduction of food and fecal wastes may be similar to those resulting from certain agricultural activities. However, greater nutrient input and localized eutrophic conditions are currently the most probable environmental effects of aquaculture activities. Extremely low oxygen levels and fish kills, of both natural stocks and cultured fish, have been known to occur in impounded wetlands where tidal and wind circulation are severely limited and the enclosed waters are subject to solar heating. In addition, there are impacts related to the dredging and filling of wetlands and other coastal habitats, as well as other modifications of wetlands and waters through the introduction of pens, nets, and other containment and production devices.

Conservation measures

- Mariculture operations should be located, designed and operated to avoid or minimize adverse impacts on estuarine and marine habitats and native fishery stocks. Those impacts that cannot be eliminated should be fully mitigated.

- Mariculture facilities should be operated in a manner that minimizes impacts on the local environment by utilizing water conservation practices and effluent discharge standards that protect existing designated uses of receiving waters.

- Federal and state agencies should cooperatively promulgate and enforce measures to ensure that diseases from culture operations do not adversely affect wild stocks. Animals that are to be moved from one biogeographic area to another or to natural waters should be quarantined to prevent disease transmission.

- To prevent disruption of natural aquatic communities, cultured organisms should not be allowed to escape; the use of organisms native to each facility's region is strongly encouraged.

- Commercial aquaculture facilities and enhancement programs should consider the genetic make-up of the cultured organisms in order to protect the genetic integrity of native fishes.

- Aquaculture facilities should meet prevailing environmental standards for wastewater treatment and sludge control.

6.6.2.7 Navigation

Navigation-related threats to estuarine, coastal, and offshore environments that have the potential to affect HMS EFH include navigation support activities such as excavation and maintenance of channels (including disposal of excavated sediments) which result in the elevation of turbidity and resuspension of contaminants; construction and operation of ports, mooring and cargo facilities; construction of ship repair facilities; and construction of channel stabilization structures such as jetties and revetments. In offshore locations the disposal of dredged material is the most significant navigation related threat, resulting in localized burial of benthic communities and degradation of water quality. In addition, threats to both nearshore and offshore waters are posed by vessel operation activities such as the discharge and spillage of oil, other hazardous materials, trash and cargo, all of which may result in localized water quality degradation and direct effects on HMS, especially eggs, larvae and neonates that may be present. Wakes from vessel operation may also exacerbate shoreline erosion, effecting habitat modification and potential degradation.

Conservation measures

- Permanent dredged material disposal sites should be located in upland areas. Where long-term maintenance is anticipated, upland disposal sites should be acquired and maintained for the entire project life.

- Construction techniques (e.g., silt curtains) should minimize turbidity and dispersal of dredged materials into HMS EFH.

- Propwashing should not be used as a dredging method.

- Channels and access canals should not be constructed in areas known to have high sediment contamination levels. If construction must occur in these areas, specific techniques, including the use of silt curtains, are needed to contain suspended contaminants.

- Alignments of channels and access canals should utilize existing channels, canals and other deep water areas to minimize initial and maintenance dredging requirements. All canals and channels should be clearly marked to avoid damage to adjacent bottoms from propwashing.

- Access channels and canals should be designed to ensure adequate flushing to avoid creating low dissolved oxygen conditions or sumps for heavy metals and other contaminants. Widths of access channels in open water should be minimized to avoid impacts to aquatic substrates. In canal subdivisions channels and canals within the development should be no deeper than the parent body of water and should be a uniform depth or become gradually shallower inland.

- To ensure adequate circulation confined and dead-end canals should be avoided by utilizing bridges or culverts that ensure exchange of the entire water column. In general, depths of canals should be minimized, widths maximized, and canals oriented towards the prevailing summer winds in order to enhance water exchange.

- Consideration should be given to the use of locks in navigation channels and access canals which connect more saline areas to fresher areas.

- To the maximum extent practicable, all navigation channels and access canals should be backfilled upon abandonment and restored to as near pre-project condition as possible. Plugs, weirs or other water control structures may also be necessary as determined on a case-by-case basis.

- All vessels transporting fuels and other hazardous materials should be required to carry equipment to contain and retrieve the spill.

- Dispersants should not be used to clean up fuels and hazardous materials unless approved by the EPA/Coast Guard after consultation with fisheries agencies.

6.6.2.8 Marinas and Recreational Boating

Marinas and recreational boating are increasingly popular uses of coastal areas. As marinas are located at the water's edge, there is often no buffering of associated pollutants released into the water column. Impacts caused by marinas include lowered dissolved oxygen, increased temperatures, bioaccumulation of pollutants by organisms, toxic contamination of water and sediments, resuspension of sediments and toxics during construction, eutrophication, change in circulation patterns, shoaling, and shoreline erosion. Pollutants that result from marina activities include nutrients, metals including copper released from antifouling paints, petroleum hydrocarbons, pathogens, and polychlorinated biphenyls. Also, chemicals commonly used to treat timber used for piers and bulkheads - creosote, copper, chromium, and arsenic salts - are introduced into the water. Other potential impacts associated with recreational boating are the result of improper sewage disposal, fuel and oil spillage, cleaning operations, and disposal of fish waste. Propellers from boats can also cause direct damage to multiple life stages of organisms, including eggs, larvae/neonates, juveniles and adults; destratification; elevated temperatures, and increased turbidity and contaminants by resuspending bottom materials.

Conservation measures

- Water quality must be considered in the siting and design of both new and expanding marinas.

- Marinas are best created from excavated uplands that are designed so that water quality degradation does not occur. Applicants should consider basin flushing characteristics and other design features such as surface and waste water collection and treatment facilities. Marina siting and design should allow for maximum flushing of the site. Adequate flushing reduces the potential for the stagnation of water in a marina and helps to maintain the biological productivity as well as reduce the potential for toxic accumulation in bottom sediments. Catchment basins for collecting and storing runoff should be included as components of the site development plan.

- Marinas should be designed and located so as to protect against adverse impacts on important habitat areas as designated by local, state, or federal governments.

- Where shoreline erosion is a non-point source pollution problem, shorelines should be stabilized. Vegetative methods are strongly preferred.

- Runoff control strategies, which include the use of pollution prevention activities and the proper design of hull maintenance areas, should be implemented at marina sites.

- Marinas with fueling facilities should be designed to include measures for reducing oil and gas spillage into the aquatic environment. Fueling stations should be located and designed so that in the case of an accident spill contaminants can be contained in a limited area. Fueling stations should have fuel containment equipment as well as a spill contingency plan.

- To prevent the discharge of sewage directly to coastal waters new and expanding marinas should install pumpout, pump station, and restroom facilities where needed. Pumpout facilities should be maintained in operational condition and their use should be encouraged to reduce untreated sewage discharges to surface waters.

- Solid wastes produced by the operation, cleaning, maintenance, and repair of boats should be properly disposed of in order to limit their entry to surface waters.

- Sound fish waste management should be part of the project design, including a combination of fish cleaning restrictions, public education, and proper disposal facilities.

- Appropriate storage, transfer, containment, and disposal facilities for liquid materials commonly used in boat maintenance, along with the encouragement of recycling of these materials, should be required.

- The amount of fuel and oil leakage from fuel tank air vents should be reduced.

- Potentially harmful hull cleaners and bottom paints (and their release into marinas and coastal waters) should be minimized.

- Public education/outreach/training programs should be instituted for boaters, as well as marina operators, to prevent improper disposal of polluting materials.

6.6.2.9 Ocean Dumping

The disposal of dredged sediments and hazardous and/or toxic materials (e.g., industrial wastes) containing concentrations of heavy metals, pesticides, petroleum products, radioactive wastes, pathogens, etc., in the ocean degrades water quality and benthic habitats. These effects may be evident not only within the immediate vicinity of the dumping activity, but also at farther locations, as well, due to current transport and the potential influence of other hydrographic features. The disposal of uncontaminated dredged material, including adverse effects on EFH and appropriate conservation measures are addressed in Section 6.6.2.4 of this chapter. Disposal of hazardous and toxic materials by U.S. flag vessels and vessels operating in the U.S. territorial sea and contiguous zone is currently prohibited under the Marine Protection Research and Sanctuaries Act (MPRSA), although under certain circumstances the Environmental Protection Agency may issue emergency permits for dumping industrial wastes into the ocean. Major dumping threats to the marine environment are therefore limited mostly to illegal dumping and accidental disposal of material in unauthorized locations. However, given the amount of debris that is deposited along the Nation's beaches every year, including hazardous materials such as medical wastes, it is evident that effects from such dumping may be substantial.

Conservation measures

- Federal and state agencies mandated with ocean dumping enforcement responsibilities should continue to implement and enforce all legislation, rules and regulations, and consider increasing monitoring efforts where warranted.

- Disposal of hazardous materials within areas designated as EFH for HMS should not be allowed under any circumstances, including emergency permit situations.

6.6.3 Cumulative Impacts

The EFH regulations suggest that cumulative impacts should be analyzed for adverse effects on EFH. Cumulative impact analysis is a locale-specific activity that will be undertaken as additional information on specific habitat locations and threats to that habitat can be accessed, and as additional spatial techniques are developed to properly analyze that information. For this FMP cumulative impacts will be addressed by describing the types of threats and effects that have been documented to have adverse effects on fish habitat, cumulatively.

Cumulative impacts on the environment are those that result from the incremental impact of actions added to other past, present and reasonably foreseeable future actions.

Such cumulative impacts generally occur in inshore and estuarine areas, and can result from individually minor, but collectively significant, actions taking place over a period of time. These impacts include water quality degradation due to nutrient enrichment, other organic and inorganic contaminants associated with coastal development, activities related to marine transportation, and loss of coastal habitats, including wetlands and sea grasses. The rate and magnitude of these human-induced changes on EFH, whether cumulative, synergistic, or individually large, is influenced by natural parameters such as temperature, wind, currents, rainfall, salinity, etc. Consequently, the level of threat posed by a particular activity or group of activities may vary considerably from location to location. These multiple effects can, however, result in adverse impacts on HMS EFH.

Wetland loss is a cumulative impact that results from activities related to coastal development: residential and industrial construction, dredging and dredge spoil placement, port development, marinas and recreational boating, sewage treatment and disposal, industrial wastewater and solid waste disposal, ocean disposal, marine mining, and aquaculture. In the late 1970s and early 1980s the country was losing wetlands at an estimated rate of 300,000 acres per year. The Clean Water Act and state wetland protection programs have helped to decrease wetland losses to 117,000 acres per year, between 1985 and 1995. Estimates of wetlands loss differ according to agency. The USDA estimates attributes 57 percent wetland loss to development, 20 percent to agriculture, 13 percent to deepwater habitat, and ten percent to forest land, rangeland, and other uses. Of the wetlands lost to uplands between 1985 and 1995, the U.S. Fish and Wildlife Service estimates that 79 percent of wetlands were lost to upland agriculture. Urban development, and "other" types of land use activities were responsible for six percent and 15 percent, respectively.

Nutrient enrichment has become a major cumulative problem for many coastal waters. Nutrient loading results from the individual activities of coastal development, non-point source pollution, marinas and recreational boating, sewage treatment and disposal, industrial wastewater and solid waste disposal, ocean disposal, agriculture, and aquaculture. Excess nutrients from land based activities accumulate in the soil, pollute the atmosphere, pollute ground water, or move into streams and coastal waters. Nutrient inputs are known to have a direct effect on water quality. For example, in extreme conditions excess nutrients can stimulate excessive algal blooms or dinoflagellate growth that can lead to increased turbidity, decreased dissolved oxygen, and changes in community structure, a condition known as eutrophication. Examples of such dinoflagellates or algae include *Gymnodinium breve* the dinoflagellate that causes neurotoxic shellfish poisoning, dinoflagellates of the genus *Alexandrium* which causes paralytic shellfish poisoning, *Aureococcus anophagefferens* the algae which causes "brown tides", and diatoms of the genus *Pseudo-nitzschia* which cause amnesic shellfish poisoning. *Pfiesteria piscicida* is a recently-described toxic dinoflagellate that has been documented in the water column in coastal areas of Delaware, Maryland, and North Carolina. Another *Pfiesteria*-like organism has been documented in St. John's River, FL. This organism has been associated with fish kills in some areas.

In addition to the direct cumulative effects incurred by development activities, inshore and coastal habitats are also jeopardized by persistent increases in certain chemical discharges. The combination of incremental losses of wetland habitat, changes in hydrology, and nutrient and chemical inputs produced over time, can be extremely harmful to marine and estuarine biota, resulting in diseases and declines in the abundance and quality of the affected resources.

Future investigations will seek to analyze cumulative impacts within specific geographic locations (certain estuarine, coastal and offshore habitats) in order to evaluate the cumulative impacts on HMS EFH. Information and techniques that are developed for this process will be used to supplement future revisions of these EFH provisions as the information becomes available.

Conservation measures

- Conservation measures for individual activities that contribute to cumulative impacts are covered in the previous sections. Participation in watershed scale planning efforts should be encouraged.

6.7 Research and Information Needs

During the identification of EFH for the HMS covered in this FMP, numerous information gaps were also identified. This was not unexpected, considering the broad distribution of these species in estuarine, coastal, neritic, and oceanic habitats, as well as their pelagic nature. In many cases the movements of these animals are poorly understood or have only been defined in broad terms. Furthermore, although the habitats through which these animals transit may be intensely studied, and the physical and biological processes fairly well understood in broad terms, there is little understanding of the particular characteristics that influence the distribution of tuna, swordfish and sharks within those systems. Unlike many estuarine or coral reef species that can be easily observed, collected or cultured, the extensive mobility and elusiveness of the species, combined with their rarity, has delayed the generation of much of the basic biological and ecological information needed to analyze their habitat affinities. Moreover, there is a general lack of technology to study habitat associations of these species *in situ*, as well as in laboratory cultures.

Based on the present state of information concerning the habitat associations of HMS, the following research and information needs have been identified. The NMFS National Habitat Research Plan lays out a framework within which research priorities may be grouped. Many of the research and information needs for HMS fit well within that plan, and it has been used to define general topics for research and information collection:

6.7.1 Tuna and swordfish

Ecosystem Structure and Function

- ✦ Investigate the influence of habitat characteristics such as temperature (e.g., the relation to thermal fronts) and salinity on tuna and swordfish distributions, spatially as well as seasonally.

- ✦ Monitor animal movements using advanced archival and satellite telemetry technology in order to better define tuna and swordfish distributions, seasonality, environmental tolerances and preferred habitats.

- ✦ Identify spawning areas and investigate the role of environmental factors which affect distribution and survival of larval and juvenile tuna and swordfish, leading to variations in year class abundance.

- ✦ Characterize submarine canyon processes, eddies, gyres, and fronts as they interact with tuna and swordfish and characterize their importance as zones of aggregation.

- ✦ Further identify major prey species for tuna and swordfish (by species), including preferred feeding areas and influences of environmental factors.

- ✦ Gain a better understanding of the life histories of tuna and swordfish, including the development of culture methods to keep tuna and swordfish alive in captivity for life history studies.

- ✦ Improve the capability to identify eggs and early life stages of the tuna and swordfish species.

Effects of Habitat Alteration

- ✦ Identify fisheries that operate in tuna and swordfish EFH and characterize threats to tuna and swordfish EFH, particularly spawning and nursery areas.

- ✦ Investigate the effects of contaminants on tuna and swordfish life stages, especially eggs and larvae; this would require the development of better laboratory culture techniques for these species.

- ✦ Determine the effects of contaminants (e.g., oil spills) in offshore epipelagic habitats where tuna and swordfish are known to spawn or otherwise aggregate.

- ✦ Identify habitat linkages between inshore and offshore habitats to better define the zone of influence for inshore activities that may adversely affect tuna and swordfish habitats.

Synthesis and Information Transfer

- ✦ Incorporate/develop spatially consistent databases of environmental conditions throughout the tuna and swordfish ranges (e.g., temperature, salinity, currents).
- ✦ Further analyze fishery dependent data to construct a clearer view of relative abundances.
- ✦ Contour abundance information to better visualize areas where tuna and swordfish are most commonly encountered.
- ✦ Construct spatial databases for early life history stages (i.e., eggs and larvae).
- ✦ Derive objective criteria to model areas of likelihood for relative abundances of tuna and swordfish based on environmental parameters.
- ✦ Define and model habitat suitability based on seasonal analyses of tolerances of environmental conditions.

6.7.2 Sharks

Ecosystem Structure and Function

- ✦ Continue the delineation of shark nurseries; establish the geographic boundaries of the summer nurseries of commercially important species.
- ✦ Determine the location of the winter nurseries of commercially important species.
- ✦ Expand the use of archival tagging and satellite telemetry in shark species, particularly of juvenile shark in seasonal migrations, to better define locations, distributions, and environmental tolerances.
- ✦ Determine if sharks return to their natal nurseries; determine if females return to the same nursery each time they give birth.
- ✦ Determine growth and survival rates of each life stage; develop age determination validations.
- ✦ Determine habitat relationships such as temperature (e.g., the relation to thermal fronts) and salinity, spatially as well as seasonally; determine the significance of areas of aggregation; determine the role of coastal/inshore habitats in supporting neonates and juveniles.

Effects of Habitat Alteration

- ✦ Document the effects of habitat alteration, including the inflow of organic and inorganic pollutants, increased turbidity, loss of coastal marshes and sea grasses, and changes in freshwater inflow, on the survival of neonates and juveniles in inshore and estuarine areas.

- Identify fisheries that operate in shark EFH and characterize threats from fishery practices to shark EFH, particularly nursery areas.

Impact and Recovery Indicators

- Analyze historical changes that have occurred in locations such as Tampa Bay, FL where trends in environmental degradation appear to have been reversed in recent years, resulting in rebounds of depressed shark (blacktip) populations.

Synthesis and Information Transfer

- Incorporate/develop spatially consistent databases of environmental conditions throughout the sharks' ranges (e.g., temperature, salinity, currents).
- Further analyze fishery dependent data to construct a clearer view of relative abundances.
- Contour abundance information to better visualize areas where sharks are most commonly encountered.
- Construct spatial databases for early life history stages (neonates and early juveniles), incorporating seasonal changes.
- Derive objective criteria to model areas of likelihood for relative abundances of sharks based on environmental parameters.
- Define and model habitat suitability based on seasonal analyses of species tolerances of environmental conditions.

6.8 Review and Revision of FMP EFH Components

Throughout the preparation of this document, numerous sources of information have been identified. Some of these have been accessed and incorporated into the identification and description of HMS EFH for this FMP. These sources include fishery scientists both inside and outside of NMFS and databases maintained in the NMFS SEFSC (e.g., Billfish, Pelagic Longline Logbook, Southeast Observer Program, Large Pelagic Survey, etc.), in the NEFSC Narragansett Laboratory (Cooperative Shark Tagging Program) and at the University of Florida (Directed Shark Observer Program), and state data from South Carolina on seine catches of sharks in state waters. The most up-to-date and reliable information available was used to describe and identify EFH for HMS in this FMP. NMFS will continue to identify other sources of information that can be incorporated into these analyses to further define EFH. Other data sources might include programs such as state habitat characterization and mapping programs (e.g., those being conducted in Florida and Texas), ichthyoplankton sampling and shark sampling programs for the Gulf of Mexico, and several recent or on-going investigations into shark nursery utilization in the Gulf of Mexico. Additionally, the COASTSPAN Program is currently investigating shark nurseries along the Atlantic coast. Additional results from this annual sampling program should be available within one to two years. This will further the effort to characterize areas that are used as pupping or nursery grounds for numerous species of shark.

The tagging, catch and bycatch information used from these databases for preparation of the EFH provisions of this FMP are part of a continuing effort to monitor HMS fisheries over broad spatial scales. They are continually updated with newly reported information and are scrutinized to ensure that a high standard is maintained. Additional analytical techniques and database queries will be possible to more fully evaluate trends and patterns in the data such as seasonal, inter-annual and inter-decadal variations. Because these databases incorporate such long time series of data, additional investigations of the historic ranges and temporal changes in species distributions should be possible in the future.

NMFS is committed to monitoring and participating in these on-going research efforts in order to update the information in the EFH provisions of this FMP. New and updated information, if available, will be reviewed as part of the annual Stock Assessment and Fishery Evaluation (SAFE) Report prepared by NMFS. If the additional information provides significant improvement over the current document, NMFS will consult with the HMS Advisory Panel and, if warranted, amend the FMP to refine the EFH descriptions, and the threats and conservation measures sections of the EFH provisions.

References Cited in Chapter 6

Aasen, O. 1963. Length and growth of the porbeagle [*Lamna nasus* (Bonnaterre)] in the North West Atlantic. Rep. Norw. Fish. Invest. 13(6): 20-37.

Arocha, F. 1997. The reproductive dynamics of swordfish *Xiphias gladius* L. and management implications in the northwestern Atlantic. PhD Dissertation, University of Miami, Coral Gables, Florida.

Auster, P.J., and R.W. Langton. 1998. The Effects of Fishing oh Fish Habitat. (manuscript).

Backus, R.H., S. Springer, and E.L. Arnold. 1956. A contribution to the natural history of the whitetip shark, *Pterolamiops longimanus*. Deep-Sea Res. 3: 178-188.

Bard, F. X. and T. Joanny. 1996. The north Atlantic albacore assessment problem. Collect. Vol. Sci. Pap. ICCAT, 43 : 339-346.

Bass, A.J., J.D. D' Aubrey, and N. Kistnasamy. 1973. Sharks of the east coast of southern Africa. I. The genus *Carcharhinus* (Carcharhinidae). Invest. Rep. Oceanog. Res. Inst., Durban, S. Afr. 33: 1-168.

Bayley, R. E. and E. D. Prince. 1993. A review of tag release and recapture files for Istiophoridae from the Southeast Fisheries Center's cooperative game fish tagging program, 1954 to present. Meet of the ICCAT standing committee on research and statistics, Madrid (Spain), Nov. 1992. Collect Vol. Sci. Pap. ICCAT SCRS/92/60.

Beardsley, G. L., Jr., N. R. Merrett and W. J. Richards.1975. Synopsis of the biology of the sailfish *Istiophorus platypterus* (Shaw and Nodder, 1791). Pages 95-120 *in:* Shomura, R. S. and F. Williams. eds. Proceedings of the International Billfish Symposium Kailua-Kona, Hawaii, 9-12 August 1972. Part 3. Species Synopses. NOAA Tech. Rep. NMFS SSRF-675. 159 p.

Bedford, D.W. 1985. Pelagic shark/swordfish drift gill net fishery. Calif. Dept. Fish. Game, Management Information Document. 74pp.

Bedford, D.W. 1987. Shark management: A case history- the California pelagic shark and swordfish fishery. In S. Cook (ed.): Sharks: an inquiry into biology, behavior, fisheries, and use. Oregon State Univ., Sea Grant Pub. Oregon: 161-171.

Berkeley, S. A. and E. D. Houde. 1981. Swordfish, *Xiphias gladius,* dynamics in the Straits of Florida. Collect. Vol. Sci. Pap. Vol. 15(2): 372 –380.

Berkeley, S.A., and W.L. Campos. 1988. Relative abundance and fishery potential of pelagic sharks along Florida's east coast. Mar. Fish. Rev. 50(1): 9-16.

Bigelow, H.B., and W.C. Schroeder. 1948. Fishes of the western North Atlantic. Pt.1. Lancelets, cyclostomes and sharks. New Haven: Mem. Sears Fdn. Mar. Res. 576pp.

Bonfil, R., R. Mena, and D. de Anda. 1993. Biological parameters of commercially exploited silky sharks, *Carcharhinus falciformis,* from the Campeche Bank, Mexico. In S. Branstetter (ed.): Conservation Biology of Sharks. NOAA Technical Report NMFS 115. U.S. Dept. Comm., Miami: 14pp.

Branstetter, S. 1987a. Age and growth validation of newborn sharks held in laboratory aquaria, with comments on the life history of the Atlantic sharpnose shark, *Rhizoprionodon terraenovae.* Copeia 1987(2): 219-300.

Branstetter, S. 1987b. Age and growth estimates for blacktip, *Carcharhinus limbatus*, and spinner, C*archarhinus brevipinna*, sharks from the Northwestern Gulf of Mexico. Copeia 1987(4): 964-974.

Branstetter, S., and G. Burgess. 1997. Commercial Shark Observer Program 1996. Final Report - MARFIN Award NA57FF0286. Gulf a& South Atlantic Fisheries Development Foundation, Inc.

Branstetter, S., and J.D. McEachran. 1986. Age and growth of four carcharhinid sharks common to the Gulf of Mexico: A summary paper. In T. Uyeno, R. Arai, T. Taniuchi, and K. Matsuura (eds.): Indo-Pacific Fish Biology: Proceedings of the Second International Conference on Indo-Pacific Fishes. Ichth. Soc. Jpn. 11pp.

Branstetter, S., and R. Stiles. 1987. Age and growth estimates of the bull shark, *Carcharhinus leucas*, from the northern Gulf of Mexico. Environ. Biol. Fishes 20(3): 169-181.

Branstetter, S., and J.A. Musick. 1994. Age and growth estimates for the sand tiger in the northwestern Atlantic Ocean. Trans. Am. Fish. Soc. 123: 242-254.

Branstetter, S., J.A. Musick, and J.A. Colvocoresses. 1987. A comparison of the age and growth of the tiger shark, *Galeocerdo cuvieri*, from off Virginia and from the northwestern Gulf of Mexico. Fish. Bull. 85: 269-279.

Brown, C.A., and S.H. Gruber. 1988. Age assessment of the lemon shark, *Negaprion brevirostris*, using tetracycline validated vertebral centra. Copeia 1988(3): 747-753.

Brown, C.A. 1996. Standardized catch rates of four shark species in the Virginia-Massachusetts (U.S.) rod and reel fishery 1986-1995. 1996 Shark Stock Assessment Workshop. NOAA/NMFS/SEFSC, Miami: 9pp.

Cailliet, G.M. and H. M. Mollet. 1997. Preliminary demographic analysis of the shortfin mako, *Isurus oxyrinchus*. Abstract. ASIH 77th Annual Meeting, June 26-July 2, 1997. University of Washington, Seattle.

Cailliet, G.M., L.K. Martin, J.T. Harvey, D. Kusher, and B.A. Welden. 1983. Preliminary studies on the age and growth of blue, *Prionace glauca*, common thresher, *Alopias vulpinus*, and shortfin mako, *Isurus oxyrhinchus*, sharks from California waters. NOAA Technical Report NMFS 8. U.S. Dept. Comm., Washington DC: 179-188.

Cailliet, G.M., L.J. Natanson, B.A. Welden, and D.A. Ebert. 1985. Preliminary studies on the age and growth of the white shark, *Carcharodon carcharias,* using vertebral bands. Mem. South. Calif. Acad. Sci. 9: 49-60.

Cailliet, G.M., and D.W. Bedford. 1983. The biology of three pelagic sharks from California waters, and their emerging fisheries: A review. Cal. Mar. Res. Comm., COFI Rep. 24: 57-69.

Cailliet, G.M., D.B. Holts, and D. Bedford. 1991. A review of the commercial fisheries for sharks on the west coast of the United States. In J. Pepperell, J. West, and P.Woon (eds): Shark conservation: Proceedings of an international workshop on the conservation of elasmobranchs, Taronga Zoo, Sydney: 13-29.

Caldwell, D.K. 1962. Postlarvae of blue marlin. Contrib. Sci. (Los Angeles) 53, 1-11.

Casey, J.G., and L.J. Natanson. 1992. Revised estimates of age and growth of the sandbar shark (*Carcharhinus plumbeus*) from the western North Atlantic. Can. J. Fish. Aquat. Sci. 49(7): 1474-1477.

Casey, J.G., and N.E. Kohler. 1992. Tagging studies on the shortfin mako shark (*Isurus oxyrhinchus*) in the western North Atlantic. Aust. J. Mar. Freshwater Res. 43: 45-60.

Castillo, G.J.L. 1992. Diagnostico de la pesqueria de tiburon en Mexico. Secretaria de Pesca, Mexico. 72pp.

Castro, J.I., and J.P. Wourms. 1993. Reproduction, placentation, and embryonic development of the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*. J. Morph. 218: 257-280.

Castro, J.I. 1983. The sharks of North American waters. Tex. A&M Univ. Press, College Station: 180pp.

Castro, J.I. 1996. The biology of the blacktip shark, *Carcharhinus limbatus*, off the southeastern United States. Bull. Mar. Sci. 59(3): 508-522.

Castro, J.I. 1993a. The biology of the finetooth shark, *Carcharhinus isodon*. Environ. Biol. Fishes 36: 219-232.

Castro, J.I. 1993b. The shark nursery of Bulls Bay, South Carolina, with a review of the shark nurseries of the southeastern coast of the United States. Environ. Biol. Fishes 38(1): 37-48.

Clark, E., and K. von Schmidt. 1965. Sharks of the central gulf coast of Florida. Bull. Mar. Sci. 15: 13-83.

Clark, E. 1963. The maintenance of sharks in captivity, with a report of their instrumental conditioning. In P.Gilbert (ed.): Sharks and survival. D.C. Heath and Co., Boston: 115-149.

Cliff, G., and S.F.J. Dudley. 1992. Sharks caught in the protective gill nets off Natal, South Africa. 6. The copper shark *Carcharhinus brachyurus* (Günther). S. Afr. J. Mar. Sci. 12: 663-674.

Collette, B. B and C. E. Nauen. 1983. FAO species catalogue Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fish. Synop., (125) Vol. 2: 137 p.

Compagno, L.J.V. 1984. FAO Species Catalog Vol.4, Part 1 and 2: Sharks of the world: An annotated and illustrated catalogue of shark species known to date. FAO Fish. Synop. 125. FAO, Rome, Italy

Cramer, J. 1996b. Estimates of the numbers and metric tons of sharks discarded dead by pelagic longline vessels. 1996 Shark Stock Assessment Workshop. NOAA/NMFS/SEFSC, Miami: 21pp.

Cramer, J. 1996a. Large pelagic logbook indices for sharks. 1996 Shark Stock Assessment Workshop. NOAA/NMFS/SEFSC, Miami: 7pp.

Cramer, J. 1996. Large pelagic logbook newsletter – 1995. NOAA Technical Memorandum NMFS – SEFC – 394, 28p.

Cummings – Parrack, N. 1996. Updated ASPIC analyses for North Atlantic albacore through 1992. Collect. Vol. Pap. ICCAT, 43 : 325-329.

Davies, J. H. and S. A. Bortone. 1976. Partial food list of 3 species of Istiophoridae Pisces from the northeastern Gulf of Mexico. Fla. Sci. 39(4)249-253. ICCAT –SCRS Vol. 45(3) : 67-85.

de Sylva, D. P. and P. R. Breder. 1997. Reproduction, gonad histology, and spawning cycles of north Atlantic billfishes (Istiophoridae). Bull. Mar. Sci. 60(3): 668-697.

Dragovich, A. 1969. Review of studies of tuna food in the Atlantic Ocean. U. S> Fish wildl. Serv. Spec. Sci. Rep.-Fish. 593:21 p.

Dodrill, J.W. 1977. A hook and line survey of the sharks found within five hundred meters of shore along Melbourne Beach, Brevard County, Florida. M.S. Thesis. Florida Inst. Techn., Melbourne, FL. 304pp.

Dragovich, A. 1970. The food of skipjack and yellowfin tunas in the Atlantic Ocean. Fish. Bull. U. S. 68(3):445-460.

Dragovich, A. 1970. The food of bluefin tuna (*Thunnus thynnus*) in the western North Atlantic Ocean. Trans. Am. Fish. Soc. 99(4):726-731.

Dragovich, A. and T. Potthoff. 1972. Comparative study of food of skipjack and yellowfin tunas off the west coast of West Africa. Fish. Bull. U. S. 70(4): 1087-1110-.

Dudley, S.F.J., and G. Cliff. 1993. Sharks caught in the protective gills nets off Natal, South Africa. 7. The blacktip shark *Carcharhinus limbatus* (Valenciennes). S. Afr. J. Mar. Sci. 13: 237-254.

Ebert, D.A. 1986. Observations on the elasmobranch assemblage of San Francisco Bay. Calif. Dep. Fish. Game, Fish. Bull. 72(4): 244-249.

FAO. 1994. FAO yearbook: Fishery statistics: Catches and landings. FAO Fisheries Series 46. Vol. 78. Italy: 700pp.

Far Seas Fisheries Research Laboratory, Shimizu. March 1978. Distribution atlas of larval tunas, billfishes and related species. Results of larval surveys by R/V Shunyo Maru and Shoyu Maru (1956 –1975). Far Seas Fish. Res. Lab. S Ser. 9. 99p.

Fourmanoir, P. 1961. Requins de la cote ouest de Madagascar. Memoires de L'Institut Scientifique de Madagascar. Tome IV. 81pp.

Fowler, H.W. 1906. Some cold blooded vertebrates of the Florida Keys. Proc. Acad. Nat. Sci. Phila. 58: 77-113.

Francis, M.P. 1996. Observations on a pregnant white shark with a review of reproductive biology. In A.P. Klimley, and D.G. Ainley (eds): Great white sharks: The biology of *Carcharodon carcharias*. Acad. Press, New York: 157-172.

Garrick, J.A.F. 1982. Sharks of the genus *Carcharhinus.* NOAA Technical Report NMFS Circ. 445. U.S. Dept. Comm., Washington DC: 194pp.

Gauld, J.A. 1989. Records of porbeagles landed in Scotland, with observations on the biology, distribution and exploitation of the species. Scottish Fisheries Research Report 45. Dept. Ag., Edinburgh, Scotland: 1-15.

Gilmore, R. G. 1983. Reproduction and embryonic development of the sand tiger shark, *Odontaspis taurus* (Rafinesque). U.S. Wildl. Serv. Fish. Bull.: 192):201-225.

Goodyear, C. P. 1997. An analysis of the possible utility of time-area closures to minimize billfish bycatch by U.S. pelagic longlines. In Review ICCAT SCRS/97/65.

Govender, A., N. Kistnasamy, and R.P. Van Der Elst. 1991. Growth of spotted ragged-tooth sharks, *Carcharias taurus* (Rafinesque) in captivity. S. Afr. J. Mar. Sci. 11: 15-19.

Grall, C. , D. P. de Sylva and E. D. Houde. 1983. Distribution, relative abundance, and seasonality of swordfish larvae. Trans. Am. Fish. Soc. 112:235-246.

Gubanov, Y.P., and V.N. Grigor'yev. 1975. Observations on the distribution and biology of the blue shark *Prionace glauca* (Carcharhinidae) of the Indian Ocean. J. Ichth. 15(1): 37-43.

Gudger, E.W.1912. Summary of work done on the fishes of Tortugas. Carnegie Inst. Washington. Year book No. 11:148-149.

Guitart Manday, D. 1975. Las pesquerias pelagico- oceanicas de corto radio de accion en la region noroccidental de Cuba. Academia de Ciencias de Cuba, Instituto de Oceanologia. Serie Oceanologia 31. 26pp.

Hanan, D.A., D.B. Holts, and A.L. Coan, Jr. 1993. The California drift net fishery for sharks and swordfish, 1981-82 through 1990-91. Calif. Dept. Fish. Game, Fish Bull. 175: 95pp.

Hanan, D.A. 1984. Analysis of the common thresher shark, *Alopias vulpinus*, in the California Bight. NOAA/NMFS/SWFSC Admin. Rep. LJ-84-10C: 34pp.

Harvey-Clark, C. 1995. Protection of sixgill sharks. In N.L. Shackell, and J.H.M. Willison (eds): Marine protected areas and sustainable fisheries. Sci. Manag. Protected Areas Ass., Nova Scotia: 286-289.

Hoff, T.B. 1990. Conservation and management of the western North Atlantic shark resource based on the life history strategy limitations of sandbar sharks. Ph.D. dissertation, Univ. of Delaware. 282pp.

Holts, D.B. 1988. Review of U.S. west coast commercial shark fisheries. U.S. Nat. Mar. Fish. Serv. Mar. Fish. Rev. 50(1): 1-8.

Holts, D.B., A. Julian, O. Sosa-Nishizaki, and N.W. Bartoo. 1996. Pelagic shark fisheries along the west coast of the United States and Baja California, Mexico. American Fisheries Society 1995 Proceedings. 37pp.

Hueter, R.E. 1991. Survey of the Florida recreational shark fishery utilizing shark tournament and selected longline data. Final report, Florida Dept. Nat. Res. grant agreement 6627. 74pp.

ICCAT. 1994. Report of the working group to evaluate Atlantic yellowfin tuna. Collect. Vol. Pap. ICCAT 1994 Vol. 42(2) : 1-25.

ICCAT. 1995. 1995 SCRS detailed report on skipjack.

ICCAT. 1997. – Report for biennial period 1996-97, 1(2).

ICES. 1995. Report of the study group on elasmobranch fishes. ICES Headquarters, Copenhagen, Denmark. ICES CM 1995/g:3. 92pp.

Idyll, C. P. and D. de Sylva. 1963. Synopsis of biological data on albacore *Thunnus alalunga* (Gmelin) 1788 (Western Atlantic). Pages 749-754 in: H. Rosa Jr. ed. Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species. FAO Fisheries Reports No. 6 (2)

Idyll, C. P. and D. de Sylva. 1963. Synopsis of biological data on yellowfin tuna *Thunnus albacares* (Bonnaterre) 1788 (Western Atlantic). Pages 771-777 in: H. Rosa Jr. ed. Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species. FAO Fisheries Reports No. 6 (2)

Jennings, S. and M. J. Kaiser. 1998. The effects of fishing on Marine Ecosystems. Advances in Marine Biology, 34, in press.

Joung, S.J., C-T Chen, E. Clark, S. Uchida, and W.Y.P. Huang. 1996. The whale shark, *Rhincodon typus*, is a livebearer: 300 embryos found in a one "Megamamma" supreme. Environ. Biol. Fishes 46: 219-223.

Kato, S., S. Springer, and M.H. Wagner. 1967. Field guide to eastern Pacific and Hawaiian sharks. U.S. Dept. Interior, Fish. Wildl. Ser., Bureau of Comm. Fish., Circular 271, Washington DC: 47pp.

Kelley, S., J. V. Gartner, W. J. Richards and L. Ejsymont. 1993. SEAMAP 1984 & 1985 – ICHTHYOPLANKTON Larval Distribution and Abundance of Carangidae, Clupeidae, Coryphaenidae, Engraulidae, Gobiidae, Istiophoridae, Lutjanidae, Scombridae, Serranidae, and Xiphiidae in the Gulf of Mexico. NOAA Tech. Mem. NMFS –SEFSC – 317. 107 p.

Kelley, S., T. Potthoff, W. J. Richards, L. Ejsymont and J.V. Gartner. 1986. SEAMAP 1983 – ICHTHYOPLANKTON Larval Distribution and Abundance of Engraulidae, Carangidae, Clupeidae, Lutjanidae, Serranidae, Sciaenidae, Coryphaenidae, Istiophoridae, Xiphiidae, and Scombridae in the Gulf of Mexico. NOAA Tech. Mem. NMFS –SEFC – 167.

Kleijn, L.J.K. 1974. Results of experimental and exploratory fishing off northeastern South America (MFR paper 1089). Mar. Fish. Rev. 36 (9): 67-77.

Kunzlik, P.A. 1988. The basking shark. Dept. of Ag. and Fisheries for Scotland. Scottish Fisheries Information Pamphlet 14: 21pp.

Laevastu, T. and H. Rosa Jr. 1963. Distribution and relative abundance of tunas in relation to their environment. Pages 1835- 1851 in: H. Rosa Jr. ed. Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species. FAO Fisheries Reports No. 6 (3)

Lutcavage, M (pers. comm.). March 2, 1998. Seminar RSMAS – MBF: Tracking the giants: Bluefin tuna biology in the Gulf of Maine.

Martinez, J.L. 1947. The Cuban shark industry. US. Fish Widl. Serv. Fishery Leaflet 250. 18pp.

Mather, F. J., lll, H. L. Clark and J. M. Mason, Jr. 1975. Synopsis of the biology of the white marlin *Tetrapturus albidus* Poey (1861). Pages 55-94 *in:* Shomura, R. S. and F. Williams. eds. Proceedings of the International Billfish Symposium Kailua-Kona, Hawaii, 9-12 August 1972. Part 3. Species Synopses. NOAA Tech. Rep. NMFS SSRF-675. 159 p.

Mather, F. J., J. M. Mason and A. C. Jones. 1995. Historical document: life history and fisheries of Atlantic bluefin tuna. NOAA Technical Memorandum NMFS-SEFSC – 370 : 165 p.

Matthews, F. D., D. M. Damkaer, L. W. Knapp, and B. B. Collette. 1977. Food of wesatern North Atlantic tunas (*Thunnus*) and lancetfishes (Alepisaurus). NOAA Tech. Rep. NMFS-SSRF-706:19 p.

McGowan, M. F. and W. J. Richards. 1989. Bluefin tuna, Thunnus thynnus, larvae in the Gulf Stream off the southeastern United States: satellite and shipboard observations of their environment. Fish. Bull. 87: 615-631.

Mid-Atlantic Fishery Management Council (MAFMC). 1998. Amendment 12 to the Summer Flounder, Scup, and Black sea Bass Fishery Management Plan, August 1998. Mid-Atlantic Fishery Management Council. Dover, DE.

Moreno, J.A., and J. Morón. 1992. Reproductive biology of the bigeye thresher shark, *Alopias superciliosus* (Lowe 1839). Aust. J. Mar. Freshwater Res. 43: 77-86.

Morgan, S. G. , C. S. Manooch III, D. L. Mason and J. W. Goy. 1985. Pelagic fish predation on *Cerataspis*, a rare larval genus of oceanic penaeoid. Bull. Mar. Sci. 36(2): 249 – 259.

Musick, J.A., S. Branstetter, and J.A. Colvocoresses. 1993. Trends in shark abundance from 1974 to 1991 for the Chesapeake Bight region of the U.S. Mid-Atlantic Coast. In S. Branstetter (ed.): Conservation biology of elasmobranchs. NOAA Technical Report NMFS 115: 1-18.

Musick, J.A. and J.A. Colvocoresses. 1986. Seasonal recruitment of subtropical sharks in Cheasapeake Bight, USA. IOC/FAO Workshop on recruitment in tropical demersal communities. Ciudad del Carmen, Mexico. Intergovernmental Oceanographic Commision Workshop Report No. 44-Supplement. pp301-311.

Nakamura, I. 1985. FAO Species Catalogue Vol. 5. Billfishes of the world. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date. FAO Fish. Synop., (125) Vol. 5. 65 p.

Nakamura, H. 1935. On the two species of the thresher shark from Formosan waters. Mem. Fac. Sci. Agric. Taihoku Imp. Univ. 14: 1-6.

Nakano, H. 1994. Age, reproduction and migration of blue shark in the North Pacific Ocean. Bull. Nat. Inst. Far Seas Fish. 31: 141-144.

Natanson, L.J. 1990. Relationship of vertebral band deposition to age and growth in the dusky shark, *Carcharhinus obscurus*, and the little skate, *Raja erinacea.* Ph.D.dissertation. University of Rhode Island:153 pp.

Palko, B. J. , G. L. Beardsley and W. J. Richards. 1981. Synopsis of the biology of the Swordfish, *Xiphias gladius* Linnaeus. FAO Fisheries Synopsis No. 127. NOAA Tech. Rep. NMFS Circular 441. 21p.

Parker, H.W., and F.C. Stott. 1965. Age, size and vertebral calcification in the basking shark, *Cetorhinus maximus* (Gunnerus). Zool. Meded. 40(34): 305-319.

Parsons, G.R. 1993. Age determination and growth of the bonnethead shark *Sphyrna tiburo*: a comparison of two populations. Mar. Biol. 117: 23-31.

Pelligrin, G. 1996. By-catch estimates and estimates of relative abundance for sharks. 1996 Shark Stock Assessment Workshop. NOAA/NMFS/SEFSC, Miami: 7pp.

Pothoff, T. and W. J. Richards. 1970. Juvenile bluefin tuna and other scombrids taken by terns in the Dry Tortugas, Florida. Bull. Mar. Sci. 20(2): 389-413.

Pratt, H.L., and J.G. Casey. 1983. Age and growth of the shortfin mako, *Isurus oxyrinchus*. In E.D. Prince and L.M. Pulos (eds), Proceedings of the international workshop on age determination of oceanic pelagic fishes: Tunas, billfishes, and sharks. NOAA Tech. Rep. NMFS 8: 175-177.

Pratt, H.L. 1979. Reproduction in the blue shark, *Prionace glauca*. U.S. Fish Wildl. Serv. Fish. Bull. 77: 445-470.

Prince, E. D., D. W. Lee, C. A. Wilson and J.M. Dean. 1986. Longevity and age validation of a tag-recaptured Atlantic sailfish, *Istiophorus platypterus*, using dorsal spines and otoliths.Fish. Bull. U.S. 84(3):493-502.

Prince, E. D., D.W. Lee and J. R. Zweifel. 1991. Estimating age and growth of young Atlantic blue marlin *Makaira nigricans* from otolith microstructure. Fish. Bull., U.S. 89:441-459.

Report of the Standing Committee of Research and Statistics (SCRS). Madrid, 20-24 October,1997

Rey, J.C., and E. Alot. 1983. Contribucion al estudio de la pesqueria de palangre del pez espada (Xiphias gladius) en el Mediterraneo occidental. ICCAT. Collective Volume of Scientific Papers. Vol.XX (SCRS-1983), No. 2-Temperate Spp. Madrid: 428-434.

Richards, W.J. and D.C. Simmons. 1971. Distribution of tuna larvae (Pisces, Scombridae) in the northwestern Gulf of Guinea and off Sierra Leone. Fish. Bull. U.S. 69(3):555-568.

Richards, W. J. 1969. Distribution and relative apparent abundance of larval tunas collected in the tropical Atlantic during Equalant I and II. Proc. Symp. Ocean. Fish. Res. Trop. Atl. – Review papers and contributions. pp. 289 – 315.

Richards, W. J. 1991. Early life history of the Atlantic bluefin tuna from the western north Atlantic. IATTC Spec. Rep. 7. 357 p.

Rivas, L. R. 1975. Synopsis of biological data on blue marlin, *Makaira nigricans* Lacepede, 1802. Pages 1-16 *in:* Shomura, R. S. and F. Williams. eds. Proceedings of the International Billfish Symposium Kailua-Kona, Hawaii, 9-12 August 1972. Part 3. Species Synopses. NOAA Tech. Rep. NMFS SSRF-675. 159 p.

Robins, C. R. 1975. Synopsis of biological data on the longbill spearfish *Tetrapturus pflugeri* Robins and de Sylva. Pages 28-38 *in:* Shomura, R. S. and F. Williams. eds. Proceedings of the International Billfish Symposium Kailua-Kona, Hawaii, 9-12 August 1972. Part 3. Species Synopses. NOAA Tech. Rep. NMFS SSRF-675. 159 p.

Russell, S.J. 1993. Shark bycatch in the Northern Gulf of Mexico tuna longline fishery, 1988-91, with observations on the nearshore directed shark fishery. In S. Branstetter (ed.): Conservation Biology of Elasmobranchs. NOAA Technical Report NMFS 115: 19-29.

Sauzo, L. 1956. Uova, larve e stadi giovanili di Teleostei. Fauna & Flora Golfo Napoli. Monogr. 38.

Schwartz, F.J. 1984. Occurrence, abundance and biology of the blacknose shark, *Carcharhinus acronotus* in North Carolina. Northeast Gulf Sci. 7 (1): 29-47.

Scoles, D. R. and J. E. Graves. 1993. Genetic analysis of the population structure of yellowfin tuna, *Thunnus albacares*, from the Pacific Ocean. Fish. Bull. U. S. 91:690-698.

Scott, G.P. 1996. Updated analysis of recent trends in catch rates of some Atlantic sharks. 1996 Shark Stock Assessment Workshop. NOAA/NMFS/SEFSC, Miami: 32pp.

Scott, G.P., P.J. Phares, and B. Slater. 1996. Recreational catch, average size and effort information for sharks in U.S. Atlantic and Gulf of Mexico waters. 1996 Shark Stock Assessment Workshop. NOAA/NMFS/SEFSC, Miami: 32pp.

Shann, E.W. 1911. VIII- A description of the advanced embryonic stage of *Lamna cornubica*. *In:* The 28th Annual Report of the Fishery Board for Scotland: 73-79.

Simpfendorfer, C. 1992. Biology of tiger sharks (*Galeocerdo cuvier*) caught by the Queensland shark meshing program off Townsville, Australia. Aust. J. Mar. Freshwater Res. 43: 33-43.

Sims, D.W., and V.A. Quayle. 1998. Selective foraging behaviour of basking sharks on zooplankton in a small-scale front. Nature 393: 460-464.

Sminkey, T.R., and J.A. Musick. 1995. Age and growth of the sandbar shark, *Carcharhinus plumbeus*, before and after population depletion. Copeia 1995(4): 871-83.

Smith, R.L. 1990. Ecology and Field Ecology. Harper Collins Publishers, USA. 922 pp.

Snelson, F.F., Jr., T.J. Mulligan, and S.E. Williams. 1984. Food habits, occurrence, and population structure of the bull shark, *Carcharhinus leucas*, in Florida coastal lagoons. Bull. Mar. Sci. 34(1): 71-80.

South Atlantic Fishery Management Council (SAFMC). 1998. Comprehensive Amendment Addressing Essential Fish Habitat in Fishery Management Plans of the South Atlantic Region, May 1998. South Atlantic Fishery Management Council. Charleston, SC.

Springer, S. 1967. Social organizations of shark populations. In P. Gilbert (ed.): Sharks, skates, and rays. John Hopkins Press, Baltimore: 149-174.

Springer, S. 1950a. An outline for a Trinidad shark fishery. Proceedings of the Gulf and Caribbean Fisheries Institute. Second Annual Session. Univ. of Miami. Coral Gables: 17-26.

Springer, S. 1960. Natural history of the sandbar shark *Eulamia milberti*. U.S. Fish. Wildl. Serv. Fish. Bull. 61 (178): 1-38.

Springer, S. 1950b. Natural history notes on the lemon shark, *Negaprion brevirostris*. Tex. J. Sci. 3: 349-359.

Springer, S. 1950c. A revision of North American sharks allied to the genus *Carcharhinus*. Am. Mus. Novit. 1451: 13pp.

Springer, S. 1979. Report on shark fishing in the western central Atlantic. WECAF report No. 3. UNDP. FAO. Panama: 39 pp.

Springer, V. G. 1964. A revision of the carcharhinid shark genera *Scoliodon, Loxodon,* and *Rhizoprionodon*. Proc. U. S. Nat. Mus. 115 (no. 3493): 559-632.

Springer, S. and R.A. Waller. 1969. *Hexanchus vitulus*, a new sixgill shark from the Bahamas. Bull. Mar. Sci. 19: 159-174.

Springer, S. 1938. Notes on the sharks of Florida. Porch. Florida Acad. Sci. 3: 9-41.

Springer, S. 1963. Field observations on large sharks of the Florida-Caribbean region. *In:* P.W. Gilbert (ed.): Sharks and Survival. D.C. Heath and Co., Boston: 95-113.

Springer, S. 1948. Oviphagous embryos of the sand shark, *Carcharias taurus.* Copeia 1948(3): 153-157.

Squire, J. L. Jr. 1963. Thermal relationships of tuna in the oceanic Northwest Atlantic. Pages 1639-1657 in: H. Rosa Jr. ed. Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species. FAO Fisheries Reports No. 6 (3)

Squire, J. L. Jr. 1963. Distribution of tuna species in the oceanic Northeast Atlantic. Pages 1477-1514 *in:* H. Rosa Jr. ed. Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species. FAO Fisheries Reports No. 6 (2)

Stevens, J.D., and K.J. Mcloughlin. 1991. Distribution, size, and sex composition, reproductive biology and diet of sharks from northern Australia. Austr. J. Mar. Freshwater Res., 42: 151-99.

Stevens, J.D. and J.M. Lyle. 1989. Biology of three hammerhead sharks *(Eusphyra blochii, Sphyrna mokarran, and S. lewini*) from northern Australia. Aust. J. Mar. Freshwater Res. 40: 129-46.

Stillwell, C.E. and N. Kohler. 1985. Food and feeding ecology of the swordfish *Xiphias gladius* in the western north Atlantic Ocean with estimates of daily ration. Mar. Ecol. Prog. Ser. 22:239-247.

Strasburg, D.W. 1958. Distribution, abundance, and habits of pelagic sharks in the central Pacific Ocean. U.S. Fish. Wildl. Serv. Fish. Bull. 138 (58): 335-361.

Strong, W.R., Jr., R.C. Murphy, B.D. Bruce, and D.R. Nelson. 1992. Movements and associated observations of bait-attracted white sharks, *Carcharodon carcharias*: a preliminary report. Aust. J. Mar. Freshwater Res. 43: 13-20.

Suda, A. 1953. Ecological study on the blue shark (*Prionace glauca* Linne). South Seas Area Fisheries Research Laboratory, Report 26, Supplement 1: 15pp.

Suda, A. 1994. Some preliminary observations on the biological characteristics of the concentrations of bluefin tuna in the Northwestern and Central North Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 42(1) : 267-270.

Tanaka, S., and K. Mizue. 1977. Studies on sharks- XI: Reproduction in female *Heptranchias perlo*. Bull. Fac. Fish. Nagasaki Univ. 42: 1-9.

Thayer, G.W., J.P. Thomas and K.V. Koski. 1996. The habitat research plan of the National Marine Fisheries Service. Fisheries. 21(5): 6-10.

Thorson, T.B. 1976. The status of the Lake Nicaragua shark: An updated appraisal. In T.B. Thorson (ed.): Investigations of the ichthyofauna of Nicaraguan lakes. School of Life Sciences, University of Nebraska-Lincoln, Lincoln: 561-574.

Thorson, T.B., and E.J. Lacy. 1982. Age, growth rate and longevity of *Carcharhinus leucas* estimated from tagging and vertebral rings. Copeia 1982(1): 110-116.

Tiews, K. 1963. Synopsis of biological data on the bluefin tuna *Thunnus thynnus* (Linnaeus) 1758 (Atlantic and Mediterranean). Pages 422- 481 in: H. Rosa Jr. ed. Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species. FAO Fisheries Reports No. 6 (2)

Toll, R. B. and S. C. Hess. 1981. Cephalopods in the diet of the swordfish, *Xiphias gladius*, from the Florida Straits. Fish. Bull. 79(4): 765 –774.

Turner and Boesch. 1987. Aquatic animal production and wetland relationships: Insights gleaned following wetland loss or gain, pp. 25-39, *in:* D. Hooks (ed.), Ecology and Management of Wetlands. croon Helms, LTD, Beckenham, Kent, UK.

Uchida, S., M. Toda, K. Teshima, and K. Yano. 1996. Pregnant white sharks and full-term embryos from Japan. In 'Great white sharks: the biology of *Carcharodon carcharias.* Klimley, P., and Ainley, D.G. (Eds.) Acad. Press, New York: 139-155.

Ulrich, G.F. 1996. Fishery independent monitoring of large coastal sharks in South Carolina. 1996 Shark Stock Assessment Workshop. NOAA/NMFS/SEFSC, Miami: 16pp.

Vas, P. 1990. The abundance of the blue shark, *Prionace glauca*, in the western English channel. Environ. Biol. Fishes 29: 209-225.

Vinnichenko, V. I. 1996. New data on the distribution of some species of tuna (Scombridae) in the North Atlantic. J. of Ichth. 36(8): 679-681.

Vodyanitsky, V.A., and I.I. Kazanova, 1954. Key to the pelagic fishes and larvae of the Black Sea. Tr. Vges. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 28:240-345 (In Russian).

Richards, W.J., T. Potthoff, S. Kelley, M. F. McGowan, L. Ejsymont, J. H. Power and R. M. Olvera. 1984. SEAMAP 1982 – ICHTHYOPLANKTON Larval Distribution and Abundance of Engraulidae, Carangidae, Clupeidae, Lutjanidae, Serranidae, Coryphaenidae, Istiophoridae, Xiphiidae and Scombridae in the Gulf of Mexico. NOAA Tech. Mem. NMFS –SEFC – 144. 51 p.

Walter, J.P., and D.A. Ebert. 1991. Preliminary estimates of age of the bronze whaler, *Carcharhinus brachyurus*, (Chondrichthyes: Carcharhinidae) from southern Africa, with a review of some life history parameters. S. Afr. J. Mar. Sci. 10: 37-44.

Wetherbee, B.M., G.L. Crow, and C.G. Lowe. 1996. Biology of the Galapagos shark, *Carcharhinus galapagensis*, in Hawaii. Environ. Biol. Fishes 45: 299-310.